

INDIAN AGRICULTURAL
RESEARCH INSTITUTE,
DELHI.

CARNEGIE INSTITUTION OF WASHINGTON

YEAR BOOK No. 27

JULY 1, 1927, TO JUNE 30, 1928

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JOHN C. MERRIAM, *President*

FORMER PRESIDENTS

*DANIEL COIT GILMAN, 1902-04

*ROBERT SIMPSON WOODWARD, 1904-20

BOARD OF TRUSTEES

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*WILLIAM E. DODGE	1902-03	*DARIUS O. MILLS	1902-09
*CHARLES P. FENNER	1914-24	*S. WEIR MITCHELL	1902-14
SIMON FLEXNER	1910-14	GEORGE W. PEPPER	1914-19
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*LYMAN J. GAGE	1902-12	*JOHN C. SPOONER	1902-07
*DANIEL C. GILMAN	1902-08	WILLIAM H. TAFT	1906-15
*JOHN HAY	1902-05	*CHARLES D. WALCOTT	1902-27
*ABRAM S. HEWITT	1902-03	HENRY P. WALCOTT	1910-24
*HENRY L. HIGGINSON	1902-19	*ANDREW D. WHITE	1902-16
*ETHAN A. HITCHCOCK	1902-09	*EDWARD D. WHITE	1902-03
*HENRY HITCHCOCK	1902-02	*HENRY WHITE	1913-27
*WILLIAM WIRT HOWE	1903-09	*ROBERT S. WOODWARD	1905-24
*CHARLES L. HUTCHINSON	1902-24	*CARROLL D. WRIGHT	1902-08

* Deceased

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904; the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

STAFF OF INVESTIGATORS

Department of Embryology:

Established 1914; Franklin P. Mall, Director 1914-1917.

GEORGE L. STREETER, Director
CARL G. HARTMAN
CHESTER H. HEUSER

MARGARET R. LEWIS
WARREN H. LEWIS

Department of Genetics:

Station for Experimental Evolution, opened in 1904, was combined with Eugenics Record Office in 1921 to form Department of Genetics.

CHARLES B. DAVENPORT, Director
A. F. BLAKESLEE, Assistant Director
H. H. LAUGHLIN, Assistant Director
AMOS G. AVERY
A. DOROTHY BERGNER
H. J. BANKER
A. M. BANTA

JOHN BELLING
M. DEMEREC
A. H. ESTABROOK
E. C. MACDOWELL
C. W. METZ
OSCAR RIDDLE

Geophysical Laboratory:

Organized 1906, opened 1907.

ARTHUR L. DAY, Director
L. H. ADAMS
EUGENE T. ALLEN
N. L. BOWEN
C. N. FENNER
R. E. GIBSON
R. W. GORANSON
J. W. GREIG
J. H. HIBBEN
F. C. KRACEK
C. J. KSANDA
H. E. MERWIN

G. W. MOREY
CHARLES S. PIGGOT
EUGENE POSNJAK
H. S. ROBERTS
J. F. SCHAIER
E. S. SHEPHERD
ROBERT B. SOSMAN (resigned)
GEORGE TUNELL
H. S. WASHINGTON
WALTER P. WHITE
FRED E. WRIGHT
E. G. ZIES

Department of Historical Research:

Organized 1903; Andrew C. McLaughlin, Director 1903-1905, J. Franklin Jameson, Director 1905-1928.

J. FRANKLIN JAMESON, Director (resigned)
EDMUND C. BURNETT
ELIZABETH DONNAN

WALDO G. LELAND (absent on leave)
CHARLES O. PAULLIN
LEO F. STOCK

Department of Meridian Astrometry:

Established 1907; Lewis Boss, Director 1907-1912.

BENJAMIN BOSS, Director
SEBASTIAN ALBRECHT
SHERWOOD B. GRANT
HEROY JENKINS

HARRY RAYMOND
ARTHUR J. ROY
W. B. VARNUM
RALPH E. WILSON

Mount Wilson Observatory:

Established 1904; George E. Hale, Director 1904-1928.

GEORGE E. HALE, Honorary Director
WALTER S. ADAMS, Director
F. H. SEARES, Assistant Director
ALFRED H. JOY, Secretary
A. S. KING, Supt. Physical Laboratory
J. A. ANDERSON
HAROLD D. BABCOCK
FERDINAND ELLERMAN
EDWIN P. HUBBLE
MILTON L. HUMASON

PAUL W. MERRILL
SETH B. NICHOLSON
FRANCIS G. PEASE
EDISON PETTIT
R. F. SANFORD
SINCLAIR SMITH
GUSTAF STRÖMBERG
CHARLES E. ST. JOHN
A. VAN MAANEN

Nutrition Laboratory:

Organized 1907, opened 1908.

FRANCIS G. BENEDICT, Director
 T. M. CARPENTER
 V. COROPATCHINSKY
 MARY D. FINN

E. L. FOX
 E. S. MILLS
 H. S. PALMER (resigned)

Division of Plant Biology:

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905. Name changed to Laboratory for Plant Physiology in 1923, and reorganized in 1928 as Division of Plant Biology, including Ecology

H. A. SPOEHR, Chairman
 FREDERIC E. CLEMENTS
 G. W. GOLDSMITH
 H. M. HALL
 WILLIAM HEUSI
 DAVID W. KECK
 FRANCES L. LONG

DANIEL T. MACDOUGAL
 H. W. MILNER
 FORREST SHREEVE
 JAMES H. C. SMITH
 H. H. STRAIN
 GODFREY SYKES

Department of Terrestrial Magnetism:

Organized 1904

LOUIS A. BAUER, Director
 J. A. FLEMING, Assistant Director
 G. BREIT
 J. E. I. CAIRNS (resigned)
 O. DAHL
 C. R. DUVAL
 V. J. EATON
 H. M. W. EDMONDS
 C. C. ENNIS
 H. W. FISK
 S. E. FORBUSH
 O. H. GISH
 JOHN W. GREEN

C. HUFF
 H. F. JOHNSTON
 A. H. KAMPE (resigned)
 P. G. LEDIG
 S. J. MAUCHLY
 W. J. PETERS
 W. J. ROONEY
 J. E. SANDERS, JR. (resigned)
 M. A. TUVE
 G. R. WAIT
 W. F. WALLIS
 F. W. WOOD

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 WILFRED C. PARKINSON
 OSCAR W. TORRESON
 F. M. SOULE

H. R. SEIWELL
 J. H. PAUL
 W. E. SCOTT
 L. A. JONES

Early American History including Middle American Archaeological Research:

A. V. KIDDER, Associate
 SYLVANUS G. MORLEY, Associate
 EARL H. MORRIS

O. G. RICKETSON, JR.
 KARL RUPPERT

Investigators at Tortugas Laboratory, Summer 1928:

PAUL BARTSCH, U. S. National Museum
 L. R. BLINKS, Rockefeller Institute
 PAUL S. CONGER, Carnegie Institution
 M. W. DE LAUBENFELS, Oberlin College
 CASWELL GRAVE, Washington University
 MYRON GORDON, Cornell University
 IVEY F. LEWIS, University of Virginia
 WARREN H. LEWIS, Carnegie Institution
 W. H. LONGLEY, Goucher College
 OLIVER H. MCCOY, Johns Hopkins University
 A. S. PEARSE, Duke University
 A. A. SCHAEFFER, University of Kansas
 HARRY BEAL TORREY, Cornell University Medical School

INVESTIGATORS—*Continued**Other Investigators:*

HENRY BERGEN, Research Associate in Early English Literature
 RALPH W. CHANEY, Research Associate in Palæobotany
 OLIVER P. HAY, Associate in Palæontology (retired)
 W. A. HEIDEL, Research Associate in Philosophy
 ELIAS A. LOWE, Associate in Palæography
 ALBERT MANN, Research Associate in Biology
 GEORGE SARTON, Associate in History of Science
 GEORGE R. WIELAND, Associate in Palæobotany
 HARRY O. WOOD, Research Associate in Seismology

Additional Research Associates connected with other Institutions:

E. B. BABCOCK (University of California), Genetics
 CARL BARUS (Brown University), Physics
 V. BJERKNES (University of Oslo, Norway), Meteorology
 J. P. BUWALDA (California Institute of Technology), Palæontology
 W. E. CASTLE (Harvard University), Biology
 *T. C. CHAMBERLIN (University of Chicago), Geology
 H. L. CLARK (Harvard University), Biology
 H. E. CRAMPTON (Columbia University), Biology
 A. E. DOUGLASS (University of Arizona), Ecology
 WALTER EDDY (Columbia University), Physiological Chemistry
 ROBERT H. GAULT (Northwestern University), Psychology
 J. ARTHUR HARRIS (University of Minnesota), Biology
 J. H. JEANS (Royal Society of London), Astronomy
 REMINGTON KELLOGG (U. S. National Museum), Palæontology
 A. E. KENNELLY (Harvard University) Terrestrial Magnetism
 D. N. LEHMER (University of California), Mathematics
 L. B. MENDEL (Yale University), Physiological Chemistry
 A. A. MICHELSON (University of Chicago), Astronomy
 R. A. MILLIKAN (California Institute of Technology), Physics
 T. H. MORGAN (California Institute of Technology), Biology
 FRANK MORLEY (Johns Hopkins University), Mathematics
 A. A. NOYES (California Institute of Technology), Chemistry
 T. B. OSBORNE (Connecticut Agric. Exp. Station), Physiological Chemistry
 J. B. OVERTON (University of Wisconsin), Botany
 GREENLEAF W. PICKARD, Terrestrial Magnetism
 W. W. PIERSON (University of North Carolina), Political Science
 *T. W. RICHARDS (Harvard University), Chemistry
 HENRY A. RUGER (Columbia University), Psychology
 HENRY N. RUSSELL (Princeton University), Astronomy
 H. C. SHERMAN (Columbia University), Chemistry
 GILBERT SMITH (Stanford University), Botany
 CHESTER STOCK (California Institute of Technology), Palæontology
 F. B. SUMNER (Scripps Institution of Oceanography), Biology
 H. U. SVERDRUP (Geofysisk Institut, Bergen, Norway), Terrestrial Magnetism
 D. H. TENNENT (Bryn Mawr College), Biology
 H. B. VICKERY (Connecticut Agric. Exper. Station), Physiological Chemistry
 J. E. WEAVER (University of Nebraska), Ecology
 LEWIS H. WEED (Johns Hopkins Medical School), Anatomy
 DAVID WHITE (National Academy of Sciences), Palæontology
 R. R. WILLIAMS (Bell Telephone Laboratories), Physiological Chemistry
 BAILEY WILLIS (Stanford University), Seismology
 CLARK WISSLER (American Museum of Natural History), Archæology
 *Deceased

ORGANIZATION, PLAN AND SCOPE

The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him January 19, 1911; so that the present endowment of the Institution has a par value of twenty-two million dollars. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

ARTICLES OF INCORPORATION

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D.

Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corpora-

tion hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

ARTICLE I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

ARTICLE II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

ARTICLE IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

ARTICLE V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

ARTICLE VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

ARTICLE VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

**MINUTES
OF THE
TWENTY-NINTH MEETING OF THE BOARD OF
TRUSTEES**

ABSTRACT OF MINUTES OF THE TWENTY-NINTH MEETING
OF BOARD OF TRUSTEES

The meeting was held in Washington in the Board Room of the Administration Building, on Friday, December 14, 1928. It was called to order at 10 a.m. by the Chairman of the Board, Mr. Root.

Upon roll-call the following Trustees responded: John J. Carty, Whitefoord R. Cole, Frederic A. Delano, Homer L. Ferguson, W. Cameron Forbes, Cass Gilbert, Myron T. Herrick, Andrew J. Montague, Wm. Church Osborn, James Parmelee, Wm. Barclay Parsons, Stewart Paton, Henry S. Pritchett, Elihu Root, Theobald Smith, William Benson Storey, William H. Welch, and George W. Wickersham. The President of the Institution, John C. Merriam, was also present.

The minutes of the twenty-eighth meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Directors of Departments and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1929 were authorized:

Insurance Fund	\$ 1,500
Pension Fund	40,000
Administration	67,850
Publication (including Division of Publications)	96,350
Departments and Divisions of Research	1,207,664
Minor Grants	133,700
General Contingent Fund	58,000
Special Emergency Reserve Fund	68,500
	1,673,564

The resignation of Martin A. Ryerson as a member of the Board of Trustees was accepted with regret, and Mr. Storey was elected a member of the Auditing Committee to take the place of Mr. Ryerson.

The meeting adjourned at 11.45 a.m.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1928

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

In conformity with Article IV, Section 2, of the By-Laws of the Carnegie Institution of Washington, the President has the honor to submit the following report on the work of the Institution for the fiscal year ending October 31, 1928, together with provisional recommendation of appropriations for the year beginning January 1, 1929.

From the group of distinguished investigators associated with the Institution we have lost a leader in research through the death of Theodore W. Richards on April 2, 1928. Dr. Richards had been Research Associate of the Carnegie Institution of Washington engaged in studies of atomic weights for a period of more than twenty-five years. His contribution is one of the most significant additions to information in this fundamental subject. The problem toward which he directed his attention is one of unusual difficulty, involving both superlative precision in experimentation and development of scientific theory on the outermost boundaries of knowledge. The definite contributions arising from these researches are presented in one hundred and twenty-nine papers listed among the publications representing work supported by the Carnegie Institution of Washington. The removal of Dr. Richards from the group of investigators with whom he was associated is an irreparable loss to science, at a time when advances in this field are of especial significance in study of the nature of matter.

In the course of the past year, activities of the Institution in the field of history have been readjusted to meet new conditions arising through resignation of Dr. J. Franklin Jameson to accept the chair of American history recently established in connection with the Library of Congress. Dr. Jameson had been associated with the Institution, as head of the Department of Historical Research, for a period of twenty-three years, previous to which he was a member of the Advisory Committee in History.

Under Dr. Jameson's leadership of the Department of Historical Research, extensive contribution to published materials has been

made through twenty-three volumes opening the way to sources of information on American history in the principal libraries and archives of America and Europe. In addition to these investigations, and a wide range of other studies, Dr. Jameson has been a continuing constructive influence in historical research through his editorship of the *American Historical Review*. During the period of his directorship Dr. Jameson held a leading place among American historical scholars, and was one of the important links connecting the Carnegie Institution with the great opportunity for historical research in the Library of Congress.

The loss of Miss Frances G. Davenport, investigator of the Department of Historical Research, and the taking over of the duties of Permanent Secretary of the American Council of Learned Societies by Waldo G. Leland, have made necessary further readjustments within the staff of the Department. The work of Miss Davenport relating to *European Treaties bearing on the History of the United States and its Dependencies* is being completed by Dr. C. O. Paullin. Mr. Leland has continued research on his own problem in connection with the Department. The program of other studies proceeds at its regular pace, and is leading to an exceptional volume of publication.

In Early American History Dr. Alfred V. Kidder has made wide studies of the work of the Institution and related investigations in the past year, and has visited all of the localities at which researches of the Institution are under way. This re-examination of the program has made possible a better vision of our problem. With the plans now formulated, the investigations in each of the several projects, while conducted with increased emphasis upon detail, have a clearer relation to the larger scheme of studies in this field in America.

As compared with earlier years, the past season's activities in Middle American Archæology have brought relatively large result in terms of scientific achievement. Improved organization of excavation work at Chichen Itzá, in Yucatan, has given to all of the investigators a somewhat larger percentage of time for study of results already attained, as also for consideration of the scientific significance of investigations under way. Similarly, at Uaxactun, the principal site of excavations in Guatemala, the very difficult work in establishing a camp and laying out a plan for study, carried through by Oliver G. Ricketson in past years, has led to opportunity for concentrated research in the present season, with attainment of results of unusual value.

In connection with the Chichen Project, Earl Morris brought to completion this year his exceptional piece of excavation on the Warriors Temple. On the basis of the completed materials, concentrated attention was given to preparation of data and illustrations for the monographic work which will constitute a report on this study. The achievement of Mr. Morris in excavation and restoration of a great structure which retains within itself the remains of several earlier buildings, and at the same time maintains ready means of access to the essential characters of all the buildings, marks a noteworthy step in development of this project.

The Warriors Temple as it stands today is of extraordinary interest to the investigator. It is not only an object of great beauty, but is one in which the work has been so handled that we see at the same time a representation of original materials in their unmodified position, along with portions of the structure in which the partly disturbed elements have been returned to their original positions. One has opportunity to study independently each stage in development of the series of buildings and at the same time see, as it were, the march of events in time.

In connection with the program for continuing study on problems of Middle American civilization, it is our hope to carry forward a plan involving not merely architecture and art, but comprising as well a careful examination of the development of this civilization in relation to its environment. To this end it is important that studies be made ranging from the general geology, ethnobotany, and ethnozoology of the region up to and including the story of those specific difficulties which have beset the human group as expressed in what may be called its medical history. Through this consideration of the record of human development we may expect to relate the history of the Maya people to problems of the present day, in such manner that the historical evidence will contribute directly toward interpretation of questions of the present and future.

In furtherance of the projects concerning Middle American history, it has also been considered important to keep continuously in view the relation of questions touching origin and development of the Maya people to those broad and fundamental problems which have to do with history of the earliest civilizations of Central America, Mexico, and southwestern regions of the United States. To this end it is important that the basic studies already far advanced by Dr. Kidder and Mr. Morris be continued as a part of the background against which research on early relationships and origins of Middle American peoples must of necessity be projected. The plan, as now worked out, represents one of the most interesting researches in the wider aspects of history that has been developed in America.

CARNEGIE INSTITUTION OF WASHINGTON

Following consideration of possible means of bettering organization of the Institution in the field of plant sciences, the Trustees authorized a re-statement of our program beginning with the year 1928. The many important activities in these subjects have been brought together as a Division of Plant Biology under chairmanship of Dr. H. A. Spoehr. It is not the intention through setting up of the present organization to extend the work of the Institution so as to cover the whole of plant biology. It is rather the purpose to obtain a somewhat better visualization of the field, and of the opportunities for effective cooperation among the interests concerned. The grouping is designed to give opportunity for maximum unity in operation of the diverse interests involved, and at the same time to increase the possibilities of effective work for each group.

The division is composed of the following sections: photosynthesis, physiology and plant growth, desert laboratory studies, plant ecology, taxonomic relations, and palæobotany. Each section is under guidance of a leading investigator. Through cooperation of Stanford University a lease for five acres of land has been obtained on the campus of the University. Provision has been made for a new laboratory to serve as headquarters of the Division, and for conduct of researches in photosynthesis, taxonomic and ecologic problems, and other subjects.

The groups of researches within the Division will operate at the localities at which the work can be conducted to best advantage. So, the Desert Laboratory at Tucson, Arizona, in immediate charge of Dr. Forrest Shreve, will continue as the point at which investigations most effectively conducted under arid conditions can be carried on with advantageous laboratory facilities, and with utilization of a diversified "campus" covering approximately 800 acres of extremely interesting desert country remaining completely protected under primitive conditions.

At the laboratories in Carmel, California, the program of researches on the physiology of tree growth continues under direction of Dr. D. T. MacDougal, who has recently had associated with him two distinguished investigators, Dr. J. B. Overton, of the University of Wisconsin, and Dr. Gilbert Smith, of Stanford University. This series of studies has made significant contribution toward interpretation of the structure and physiological processes of the tree. It has come at a critically important time when intensive investigation of such problems is of large importance in the general field of forest research.

Intimate relation of the sections of the Division to each other will make possible in increased measure the utilization of the highest

technique of each of the groups for solution of problems of the whole Division.

In organization of this Division, there has been developed also a closer relation between investigators in the fields represented and those in other departments of the Institution. Especially is this true in relation to the Department of Genetics. It thus becomes possible to develop an intensified program of plant research involving the present Division of Plant Biology, the plant geneticists of the Department of Genetics, and associated investigators represented especially by Dr. E. B. Babcock, of the University of California, who through his researches in genetics is already cooperating with Dr. H. M. Hall of the Division of Plant Biology.

The collaboration of sections of the Division of Plant Biology and their relation to outside agencies is effectively illustrated in plans for a conference on the influence of physical factors upon tree growth to be held in Washington in December of the present year, under leadership of Dr. MacDougal. This will be the second conference on questions in this field held by the Institution, the first having developed in 1922 through suggestion of Dr. F. E. Clements. The second conference will relate itself specifically to consideration of the known influence of physical factors on development of the tree, based upon studies in physiology and morphology or structure as shown especially in formation of wood tissue. The evidence actually available will be considered with special relation to the meaning of variation in annual rings taken as an expression of influence by climatic and other factors upon growth of the tree. The participating investigators will represent a wide range of interests, reaching from physiology of tree growth to questions touched by climatologists, geologists, and physicists. One of the most interesting contributions will come through studies on this problem by Dr. A. E. Douglass, of the University of Arizona, as represented in his work on *Climatic Cycles and Tree Growth: A Study of the Annual Rings of Trees in Relation to Climate and Solar Activity*.

The sailing of the ship *Carnegie* from Washington on May 1, 1928, initiated the seventh cruise of this extremely interesting vessel, devoted primarily to observations on magnetic and electric variations but now extending its work more widely to reach correlated aspects of physical oceanography. Not on any previous cruise has the non-magnetic ship carried so full an equipment of apparatus and so widely experienced a staff. The activities, in addition to those in terrestrial magnetism and atmospheric electricity, will range through physical

Department of
Terrestrial
Magnetism

studies of the atmosphere, chemical analysis of sea-water, deep dredging for physical and biological purposes, and mapping of the sea floor.

The observational work of the *Carnegie* is correlated with an extremely careful program of researches centering upon the general problem of the earth as a magnet. The investigations on this cruise of the next three years will bring back abundant material relative to changes in the earth's magnetism which have occurred since the last observations at the localities visited. Collectively, the observational and theoretical studies will add to our knowledge of those elusive magnetic influences on the earth that have been scientifically so interesting and humanly so important in recent centuries.

The work of the Department of Terrestrial Magnetism as expressed in the voyage of the *Carnegie* is only one phase of the observational program having to do with collection of data in study of physical problems of the earth. Many land voyages carried out in the course of recent years have accumulated a vast bulk of information obtained through corresponding researches on the continents. At two permanent observation stations on approximately opposite sides of the earth—one high in the Andes at Huancayo, Peru, the other at Watheroo in Southwestern Australia—there are being conducted experiments of unique interest directed toward investigation of the natural electric currents flowing in the earth, and of their relation to phenomena of the earth's magnetic changes. These experiments are made with apparatus involving lines of insulated wire, from one and one-half to five miles long, lying at right-angles to each other, one extending true north and south and another true east and west.

Never before has there been established such a widely extended and at the same time intensively operated plan of study of this particular group of physical characteristics in the earth. But, as much as may be learned by these methods, it is clear that the ultimate problem can be understood only when these researches are related to fundamental investigation of the structure and magnetic properties of matter. To this end the department has been conducting a series of intimate studies of magnetic phenomena by use of specially constructed apparatus. These researches are carried on in correlation with investigations conducted by many other institutions, and in collaboration with a number of associates representing other scientific agencies of this country and Europe.

The laboratory work of the Department of Terrestrial Magnetism is directed most intensively at the present time to consideration of certain aspects of atomic physics. Special effort has been made to

approach the problem by paths somewhat different from those heretofore followed. The result has been a series of researches, on the structure of the atom with particular reference to the nucleus, by a group of investigators including Dr. Gregory Breit, Dr. M. A. Tuve, and Mr. Odd Dahl.

For the purpose of these studies it has been necessary to develop in the laboratory higher electric voltages than have been obtained heretofore. With relatively inexpensive apparatus electric pressures of 5,200,000 volts have been secured by Dr. Breit and Dr. Tuve. The purpose of development of this apparatus is to secure relatively high-speed particles to be used in an attempt to penetrate the nuclear portion of the atom. The contribution of these investigations relates intimately to a wide range of studies being conducted in this country and in Europe on the fundamental structure of matter. It has been extremely important to recognize that the ultimate objectives of the department can be attained only by such intimate correlation of observational work, including the earth as a whole, with detailed researches on the electro-magnetic properties of matter undertaken in the laboratory.

The department has been active in developing cooperative work with other divisions of the Institution and with related agencies. Especially significant have been the investigations set up jointly by the Geophysical Laboratory and the Department of Terrestrial Magnetism on influence of high pressure and high temperature upon magnetic properties of materials in the interior of the earth. This research has resulted in an important contribution now being prepared for publication. Similarly important is cooperation between Mount Wilson Observatory and Terrestrial Magnetism in study of the relation between magnetic phenomena of the sun and variations in the magnetic and electric conditions on the earth.

The Nutrition Laboratory has been bringing to bear an extraordinary technique, worked out with extreme care both theoretically and practically, for examination of a specific group of phenomena, namely, the energy developed by the human machine. A study of the relation of this problem to various activities within the Institution by the Director, Dr. Benedict, has brought out the fact that the same type of question has arisen in various forms in investigations by many departments.

Relation between the work of Dr. Benedict and that in other divisions of the Institution has resulted in real benefit to the researches in all groups of cooperating investigators. Joint studies in this field have been mentioned in other reports referring to the investiga-

tions of Dr. Benedict and Dr. Riddle, of the Department of Genetics, on relation of the thyroid to metabolism in study of development in the pigeon. Corresponding cooperative arrangements have been made on study of enzymes, with Dr. H. C. Sherman, Research Associate of the Institution at Columbia University, and with Dr. L. B. Mendel, of Yale University, in researches on changes in growth of the rat produced by variation of food. Similar investigations have also been considered by Dr. Benedict in cooperation with the Carnegie Foundation on problems concerning physiology of exercise in studies of athletics, and with the Division of Early American History in study of metabolism in various peoples.

As illustration of the extent to which cooperative arrangements may be developed, Dr. Benedict has recently made arrangement with the Department of Terrestrial Magnetism through which members of that staff have been trained to make tests of metabolism of peoples in the various countries in which stations of the Department of Terrestrial Magnetism are located, and in regions where the ship *Carnegie* will touch in the course of the three-year cruise upon which it has just entered.

The Department of Meridian Astrometry was established for the purpose of preparing a general catalogue of positions and motions of stars out to the seventh magnitude. This work, established in March 1907, is rapidly approaching completion. Publication of the San Luis Catalogue, just issued, marks one of the first divisions of the work to be finished. The contribution made by this study is of great significance in many fields of astronomy, giving as it does the most precise determination of position of a multitude of stars. In the results of this work lie important data needed in consideration of movements of the stars, and giving certain phases of information required in forming estimate of the true nature of our own star system represented mainly by the Milky Way.

The magnitude of the task in this department is indicated in the statement that preparation of the catalogues has occupied a considerable staff for twenty-one years, since the time when Dr. Lewis Boss, father of the present Director, Mr. Benjamin Boss, entered upon the investigation. During this period approximately \$708,500 has been expended for the work.

Following completion of the investigations in this project, it is desired to present along with the General Catalogue a summary of collateral results attained during the course of these studies. Much

of general interest and importance has been derived in the progress of the work.

The biological station, established by Dr. Alfred G. Mayor on the Dry Tortugas keys seventy-five miles west of Key West, was occupied as a point of exceptional interest, at which tropical fauna and flora could be found in a region bordering the Gulf Stream. At the time of the death of Dr. Mayor, many problems of interest were being studied intensively, and work has been continued along the lines then laid down. The program of studies set up by Dr. Mayor rested fundamentally upon his personal influence. The group of investigators was stimulated by his enthusiasm and guided by his exceptional vision. When Dr. Mayor's work ended there was clearly question whether at such a remote locality it would be advisable to continue these activities beyond the steps needed in carrying to completion specific researches under way.

With cooperation of the investigators already concerned with special problems at the Tortugas Station, and with assistance of Dr. W. H. Longley as Executive Officer, there was put in operation a plan for utilization of the station for the purposes defined by Dr. Mayor, plus the opening of opportunity for use of these advantages by investigators of the Institution or cooperating agencies when there are problems which can be considered to better advantage at Tortugas than at any other locality. On this basis the Institution has been able to assist a group of researchers especially desirous of utilizing the advantages of this location. Contribution has been made toward payment of travel expenses, and subsistence has been furnished at the station. The result has been gradually increasing development of important investigations, until today the station has reached its full capacity.

Of the various types of contacts of the Carnegie Institution with the scientific and lay public the broadest and most definite influence has been through publication of results of researches. There is to be counted in addition the direct expression of work completed appearing in lectures and exhibits presented in the name of the Institution. There is also the indirect influence unconsciously exerted through personal and administrative relations in conduct of regular operations of the Institution.

CARNEGIE INSTITUTION OF WASHINGTON

The influence of published results of scientific work is always far-reaching, but the total value depends in considerable measure upon whether the data are made available quickly and fully for the agencies, or interests, or groups of people to whom they can be most useful.

The contacts of the Institution with the outside world through its publication program have shifted steadily toward a position in which our technical books are printed and issued more quickly, obtain more diversified distribution through varying sizes of editions, are distributed to a wider group of agencies, and have broader and more rapid distribution to those specialists who have largest use for them. As indicated in earlier reports, various methods are now utilized by which, in a dignified way, the more generally used technical books have increased sale through the book trade, as is illustrated in the case of Sarton's *Introduction to the History of Science*.

It may not be wise to attempt translation of all scientific treatises into popular language, but it may be assumed that, with the plans now developing, future years will bring an increasing group of publications of general interest in the form of books and by other means through which the wide-reading public may have acquaintance with the work as it proceeds.

The carefully prepared releases, arising from accounts of researches furnished by the investigators, and appearing in form acceptable to the public press, have served as a means of extending clear statements regarding work in progress to many millions of persons. There is increasing demand for such announcements, and there is reason to believe that they serve as an important medium for transmitting information regarding results obtained, both to the lay public and to the scientific world. For the coming year special arrangements have been made for issuing these statements, together with lists of publications, to all members of the Institution and to others who may be interested.

There is continuous study of the plan of the Institution with reference to methods by which the materials it produces reach those individuals, and groups, and institutions through which the knowledge obtained can become effective in human use. It is to be assumed that refinement of this process will not only give somewhat increased value to the work accomplished, but that it will also furnish a larger measure of satisfaction to those engaged in the researches through recognition of widened utilization and appreciation of results.

REPORT OF THE PRESIDENT, 1928

In the course of the past year the Finance Committee has carried through a program of reinvestment of far-reaching importance to the Institution. The Committee has continued to hold investments within the group of securities of the highest type and at the same time has added to income. The most extensive readjustment is that brought about by the selling of a large block of the five per cent bonds to the United States Steel Corporation. It is believed that the net result of the reinvestments will materially increase the income for the coming year, and will make possible for the next budget a relatively large addition to the Special Emergency Reserve Fund established two years ago.

It is important to note that only through establishment of a source of support of the type of the Special Emergency Reserve Fund can the Institution care for large projects requiring special expenditures beyond the limits of the normal Contingent Fund. It is from this reserve fund that the Institution has obtained the amount required for construction of the new laboratory for Plant Biology.

It is clear that with increasing requirements for research, and with the natural tendency of every problem to widen its scope as study proceeds, the financial future of the Institution must itself be the subject of continuous investigation. Successful administration will depend either upon ability to build up income to correspond in some measure to normal increase of research needs, or upon the possibility of so organizing the investigations that the limits of the program may be narrowed from time to time, in order to make it feasible to keep researches under way on the highest level of effectiveness.

The provision made for various types of insurance as set up by the Institution has thus far met all burdens that have developed. The Insurance Fund established to cover property damage has increased to such an extent that annual interest on the fund now almost equals the sum formerly appropriated for each year. At the present rate of development the accrued interest will more than cover the amount of required additions in 1930. It may be desirable to add a modest sum each year in order to keep the fund in such a condition as to meet without difficulty even the largest disaster which might conceivably affect the work of the Institution.

In the past year, in addition to other forms of insurance, liability policies were taken out to cover various types of activity. The extension of this system of insurance gives added reason for moderate increase of the Insurance Fund.

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The Pension Fund has also met the requirements placed upon it up to the present time. The peak of the load is calculated to come within the course of the next ten years, in which there will be relatively large supplementary payments to cover annuities on the part of those whose retirement comes relatively close to the date when the annuity system was established. It is conceivable that within the period from 1930 to 1940 the Institution may be called upon to make some addition to the sum of \$40,000 which has been appropriated annually for this purpose. Arrangement for a careful study of the situation is being made through the courtesy and cooperation of the Teachers Insurance and Annuity Association of America.

REPORT OF THE PRESIDENT, 1928

FINANCIAL STATEMENT

The sources of funds available for expenditure during the fiscal year (including appropriations made by the Trustees, December 9, 1927, and revertsments and transfers made during the year), the amounts allotted by the Executive Committee during the year, and the balances unallotted at the end of the year are shown in detail in table A.

A—Financial statement for fiscal year ending October 31, 1928

	Balances unallotted Oct. 31, 1928.	Trustees' appropria- tion Dec. 10, 1928.	Revert- ments and transfers Nov 1, 1927 to Oct. 31, 1928.	Total available 1928.	Executive Committee allotments 1928.	Transfers by Execu- tive Com- mittee.	Unallotted balances Oct. 31, 1928.
Large Grants:							
Early American History		\$69,965	\$4,200.00	\$74,185.00	\$74,185.00		
Embryology		57,600		57,600	57,600		
Genetics		131,086	2,641.67	133,727.67	133,727.67		
Geophysical Laboratory		172,284	3,731.10	176,015.10	176,015.10		
Historical Research		40,220	600	40,820.00	40,820.00		
Marine Biology		13,560		13,500.00	13,500.00		
Meridian Astrometry.		38,420	700	39,120.00	39,120.00		
Mt. Wilson Observatory		238,410	4,100.00	242,510.00	242,510.00		
Nutrition Laboratory		50,090	1,000.00	51,090.00	51,090.00		
Plant Biology		110,680	5,425	116,105	116,105		
Terrestrial Magnetism		255,670	5,910.00	261,580.00	261,580.00		
Minor Grants	\$646.64	174,700	23,454.63	198,801.27	191,284.36		\$7,516.91
Publications	12,686.07	96,230	2,071.06	110,987.13	104,854.99		6,132.14
Administration		67,600	5,000.00	72,600.00	72,600.00		
Insurance Fund		1,500		1,500.00	1,500.00		
Pension Fund		40,000		40,000.00	40,000.00		
General Contingent Fund	11,032.48	50,200	33,666.37	94,898.85	7,377.75	\$62,937.77	24,583.33
Sp'l Emer., Reserve Fund		31,500		31,500.00	31,500.00		
	24,305.19	1,639,655	92,519.83	1,770,040.02	1,655,369.87	62,937.77	38,232.38

CARNEGIE INSTITUTION OF WASHINGTON

The aggregates of receipts from interest on endowment, from interest on bond investments and bank deposits, from sales of publications, Receipts and from refunds on grants, and from miscellaneous Expenditures of the Institution sources, for each year since the foundation of the to Date Institution are shown by table B; the grand total of these to date is \$61,502,218.29.

B—Aggregate of financial receipts

Year ending Oct. 31.	Interest on endowment.	Interest on bonds and bank deposits.	Sales of publications	Refunds on grants	Miscellaneous items.	Total.
1902	\$250,000.00	\$9.70	.....	.....	\$1,825.52	\$251,835.22
1903	500,000.00	5,867.10	\$2,286.16	.....	101.57	508,254.83
1904	500,000.00	33,004.26	2,436.07	\$999.03	.....	536,439.36
1905	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944.73
1911	975,000.00	14,517.63	10,892.26	4,236.87	923.16	1,005,569.97
1912	1,100,000.00	31,118.41	11,496.13	1,658.88	96,035.01	1,240,308.42
1913	1,103,355.00	46,315.60	12,208.66	3,227.53	345,769.95	1,510,876.74
1914	1,105,084.17	59,298.63	11,402.40	7,819.70	577,305.77	1,760,910.67
1915	1,100,375.00	67,888.31	10,297.79	8,322.87	28,162.79	1,215,046.76
1916	1,100,375.00	83,626.38	12,544.16	1,450.12	153,204.40	1,351,200.06
1917	1,100,408.75	100,702.60	11,921.35	32,950.22	179,611.97	1,425,594.89
1918	1,110,427.45	120,464.02	9,921.00	39,833.23	255,354.60	1,536,000.30
1919	1,112,441.25	138,700.73	12,837.58	53,549.98	214,498.99	1,532,028.53
1920	1,112,441.25	159,559.03	18,393.79	4,088.63	176,249.81	1,470,732.51
1921	1,112,441.25	170,211.22	16,684.51	4,068.69	210,518.96	1,513,924.63
1922	1,112,504.52	175,021.09	14,081.84	9,395.66	34,527.38	1,345,530.49
1923	1,114,541.13	192,287.72	13,841.76	9,739.17	1,720,808.90	3,051,218.68
1924	1,115,187.58	193,368.98	11,994.21	18,663.38	409,712.28	1,748,926.43
1925	1,181,585.00	197,696.51	13,680.74	14,315.03	825,156.17	2,232,433.45
1926	1,156,795.00	199,418.02	14,039.02	44,766.64	167,898.35	1,582,917.03
1927	1,186,397.70	199,038.63	10,032.42	19,049.80	1,814,461.93	3,228,980.48
1928	1,496,737.48	218,755.01	10,924.25	31,144.42	26,068,636.68	27,826,197.84
Total	24,896,097.53	2,525,698.69	274,860.66	318,281.05	\$3,487,280.36	61,502,218.29

* Of this amount \$29,749,853.62 came from the sale of bonds; \$51,265.74 from the Colburn Estate; and \$3,613,135.42 from the Carnegie Corporation of New York.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be classified under five heads: (1) Investments in bonds; (2) large projects; (3) minor

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grants and payments from Pension, Insurance, and General Contingent Funds; (4) publications; (5) administration. Table C shows the actual expenditures under these heads for each year since the foundation of the Institution.

C—Aggregate of expenditures

Year ending Oct. 31.	Purchase of bonds.	Large projects.	Minor grants and payments from Pension, Insurance, and General Contingent Funds	Publications.	Administration.	Total.
1902	.....	.....	\$4,500.00	.....	\$27,513.00	\$32,013.00
1903	\$100,475.00	.....	137,564.17	\$938.53	43,627.66	282,605.36
1904	196,159.72	\$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910	57,889.15	427,941.40	83,464.63	49,067.00	44,011.61	662,373.79
1911	51,921.79	454,609.75	72,048.80	37,580.17	45,455.80	661,616.31
1912	436,276.03	519,673.94	103,241.73	44,054.80	43,791.13	1,147,037.63
1913	666,428.03	698,337.03	110,083.06	53,171.59	43,552.89	1,571,572.60
1914	861,864.23	817,894.52	107,507.55	44,670.55	44,159.54	1,876,096.39
1915	206,203.21	770,488.58	109,569.37	46,698.56	48,224.04	1,181,183.76
1916	473,702.70	638,281.41	99,401.26	73,733.38	49,454.08	1,334,572.83
1917	502,254.05	695,813.07	100,746.13	62,884.61	48,766.29	1,410,464.15
1918	528,565.55	693,780.00	170,470.74	44,394.83	49,118.76	1,486,329.88
1919	438,960.29	845,123.82	203,810.84	68,964.23	55,742.83	1,612,602.01
1920	464,279.57	876,437.28	159,633.49	95,933.10	68,739.90	1,665,023.34
1921	109,390.25	981,186.46	171,895.22	81,388.33	58,730.11	1,402,590.37
1922	50,431.05	975,149.20	192,325.46	96,227.01	56,405.15	1,370,537.87
1923	1,715,537.72	930,395.95	232,344.69	89,402.06	63,493.46	3,031,173.88
1924	440,921.24	939,739.67	230,291.90	87,790.74	65,076.47	1,763,820.02
1925	861,583.20	979,615.36	225,307.45	103,531.67	67,266.71	2,237,304.39
1926	178,817.80	1,060,525.36	254,977.20	84,526.23	65,871.48	1,644,718.07
1927	1,623,071.17	1,164,136.05	258,709.17	85,221.42	67,283.11	3,198,420.92
1928	26,010,438.19	1,208,942.20	281,308.76	93,571.02	73,052.60	27,667,312.77
Total	36,277,088.59	17,823,807.20	3,991,877.10	2,575,968.26	1,385,706.94	61,053,448.09

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On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings and equipment of departmental establishments, the following sums have been expended since the foundation of the Institution:

Investments in Property

D—Real estate and equipment, original cost

Administration:		
Building, site and equipment (Oct. 31, 1928).....		\$341,404.17
Division of Plant Biology		
Buildings and grounds.....	\$58,074.56	
Laboratory and library.....	54,371.89	
Operating appliances.....	13,565.20	
		126,011.65
Department of Embryology (Sept. 30, 1928):		
Library	2,052.88	
Laboratory	9,797.11	
Administration	4,701.21	
		16,551.20
Department of Genetics (Sept. 30, 1928):		
Buildings, grounds, field.....	281,615.57	
Operating	22,174.97	
Laboratory apparatus.....	15,478.67	
Library	30,116.17	
Archives	45,488.90	
		394,874.28
Geophysical Laboratory (Sept. 30, 1928):		
Building, library, operating appliances.....	202,201.79	
Laboratory apparatus.....	116,073.95	
Shop equipment.....	13,910.27	
		332,186.01
Department of Historical Research (Sept. 30, 1928):		
Office	3,763.06	
Library	5,379.54	
		9,142.60
Department of Marine Biology (Sept. 30, 1922):		
Vessels	30,930.43	
Buildings, docks, furniture and library.....	12,130.86	
Apparatus and instruments.....	9,322.55	
		52,383.84
Department of Meridian Astrometry (Sept. 30, 1928):		
Apparatus and instruments.....	3,746.84	
Operating	4,747.56	
		8,494.40
Nutrition Laboratory (Sept. 30, 1928):		
Building, office and shop.....	127,449.88	
Laboratory apparatus.....	31,086.63	
		158,530.51
Mount Wilson Observatory (Aug. 31, 1928):		
Buildings, grounds, road and telephone line.....	199,324.64	
Shop equipment.....	44,423.27	
Instruments	583,522.75	
Furniture and operating appliances.....	182,102.90	
Hooker 100-inch reflector.....	600,159.86	
		1,609,533.42
Department of Terrestrial Magnetism (Sept. 30, 1928):		
Building, site and office.....	211,711.16	
Vessel and survey equipment.....	214,802.34	
Instruments, laboratory and shop equipment.. ..	139,642.41	
		566,155.91
		3,615,267.99

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PUBLICATIONS

Sales of Publications and Value of those on Hand Table E shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution.

E—Table showing sales of publications

Year	Index Medicus.	Year Book.	Miscellaneous books.
1903.....	\$2,256.91	\$29.25	.....
1904.....	2,370.47	52.85	\$12.75
1905.....	2,562.76	44.75	431.44
1906.....	2,970 56	37.60	1,341.52
1907.....	3,676.71	56.50	2,292 89
1908.....	3,406.19	99.65	4,371 67
1909.....	4,821.85	73.01	6,287.21
1910.....	4,470.50	100.70	5,899 05
1911.....	4,440 21	85.50	6,366 55
1912.....	4,652 14	61.65	6,782 34
1913.....	4,992 02	75.95	7,140 69
1914.....	5,079.16	49.65	6,273.59
1915.....	5,010 21	47.60	5,239.98
1916.....	4,382.19	46 60	8,115.37
1917.....	4,616 21	51.55	7,253.59
1918.....	4,324 29	21.10	5,575.61
1919.....	4,267.95	93.30	8,476.33
1920.....	5,451.86	40.50	12,901.43
1921.....	6,277 32	50.55	10,356.64
1922.....	5,774.59	59 25	8,248 00
1923.....	5,777.46	70.10	7,994.20
1924.....	4,533.68	31 00	7,429.53
1925.....	5,636.25	25.00	8,019 49
1926.....	5,728.31	41.40	8,269.31
1927.....	1,650.65	59.67	8,322 10
1928.....	887.85	87.80	9,948 60
Total....	110,018 30	1,492.48	163,349 88

At the end of the fiscal year there are on hand 91,529 volumes of miscellaneous publications and Year Books, having a sale value of \$266,098.20, also 1,523 complete volumes of the Index Medicus which, together with miscellaneous numbers, have a value of \$15,990.75.

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Growth and Extent of Institution's Publications The data furnished in table F are of statistical interest in respect to the work of publication of the Institution. 573 volumes, which embrace a total of 166,125 pages of printed matter, have thus far been issued.

F—Table showing number of volumes, number of pages (octavo and quarto), and totals of pages of publications issued by the Institution for each year and for the twenty-seven years from 1902 to 1928

Year	Number of volumes issued.	Number of octavo pages.	Number of quarto pages.	Total number of pages.
1902.....	3	46	.....	46
1903.....	3	1,667	.....	1,667
1904.....	11	2,843	34	2,877
1905.....	21	3,783	1,445	5,228
1906.....	19	3,166	1,288	4,454
1907.....	38	6,284	3,428	9,712
1908.....	28	4,843	2,485	7,328
1909.....	19	3,695	1,212	4,907
1910.....	29	3,274	4,831	8,105
1911.....	30	5,062	1,670	6,732
1912.....	23	3,981	2,044	6,025
1913.....	29	6,605	2,752	9,357
1914.....	23	4,978	1,934	6,912
1915.....	23	4,686	1,466	6,152
1916.....	35	9,478	2,430	11,908
1917.....	21	4,464	2,691	7,155
1918.....	17	3,073	1,120	4,193
1919.....	29	5,834	2,431	8,265
1920.....	23	3,962	3,710	7,672
1921.....	18	4,068	1,398	5,466
1922.....	24	4,566	2,039	6,605
1923.....	20	6,459	604	7,063
1924.....	17	4,665	834	5,499
1925.....	24	3,970	1,277	5,247
1926.....	14	4,552	850	5,402
1927.....	17	4,520	2,089	8,609
1928.....	15	4,495	1,044	5,539
Total...	573	119,019	47,106	166,125

The publication of 18 volumes has been authorized by the Executive Committee during the year, at an aggregate estimated cost of \$72,150. The following list gives the titles and names of authors of the publications issued; it includes 15 volumes, with an aggregate of 4,495 octavo pages and 1,044 quarto pages. Eleven additional volumes are now in press

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LIST OF PUBLICATIONS ISSUED BY CARNEGIE INSTITUTION OF WASHINGTON DURING THE YEAR ENDING OCTOBER 31, 1928.

- Year Book No. 26, 1926-27. Octavo, xix+48+404 pp., 1 plate, 3 figs.
- No. 215-B. Vol. II. Clark, Victor S. History of Manufactures in the United States, 1860-1914. Octavo, xvi+949 pp., 10 pls.
- No. 289. Vol. II. Douglass, A. E. Climatic Cycles and Tree-Growth. A study of the Annual Rings of Trees in relation to Climate and Solar Activity. Octavo, vi+166 pp., 9 pls., 19 figs.
- No. 299. Vol. IV. Burnett, E. C. Letters of Members of the Continental Congress: January 1 to December 31, 1779. Octavo, lxvi+545 pp.
- No. 371. Vol. III. Bassett, John S. Correspondence of Andrew Jackson. Octavo, xxxiv+464 pp.
- No. 379. Taylor, Wm. Randolph. The Marine Algæ of Florida with Special Reference to the Dry Tortugas. (Paper from Tortugas Laboratory of the Carnegie Institution of Washington, Vol. XXV.) Quarto, vi+219 pp., 37 pls., 3 figs.
- No. 381. Du Toit, Alexander L. Geological Comparison of South America with South Africa. With a Paleontological Contribution: Upper Carboniferous Fossils from Argentina, by F. R. C. Reed. Octavo, viii+158 pp., 16 pls., 1 map, 7 figs.
- No. 383. Barus, Carl. Acoustic Experiments with the Pinhole Probe and the Interferometer U-Gage. Octavo, x+158 pp., 258 figs.
- No. 384. Nichols, E. L., H. L. Howes, and D. T. Wilber. Cathodo-Luminescence and the Luminescence of Incandescent Solids. Octavo, vii+330 pp., 176 figs.
- No. 386. Boss, Lewis, and Benjamin Boss; assisted by Richard W. Tucker, Arthur J. Roy, and William B. Varnum. San Luis Catalogue of 15,333 Stars of the Epoch 1910. Quarto, lvii+307 pp.
- No. 387. Dyar, Harrison G. The Mosquitoes of the Americas. Octavo, iv+616 pp., 123 plates.
- No. 388. Jochelson, Waldemar. Archæological Investigations in Kamchatka. Quarto, viii+88 pp., 19 pls., 1 map, 83 figs.
- No. 389. Hall, Harvey M. The Genus *Haplopappus*: A Phylogenetic Study in the Compositæ. Octavo, viii+391 pp., 16 pls., 114 figs.
- No. 393. Contributions to Palæontology from the Carnegie Institution of Washington. Octavo, v+58 pp., 13 pls., 25 text-figs.
- Merriam, John C., and Charles W. Gilmore.—An Ichthyosaurian Reptile from Marine Cretaceous of Oregon.
- Merriam, John C., and Chester Stock.—A Further Contribution to the Mammalian Fauna of the Thousand Creek Pliocene, Northwestern Nevada.
- Stock, Chester.—A Peccary from the McKittrick Pleistocene, California.
- Stock, Chester.—*Tanupolama*, a New Genus of Llama from the Pleistocene of California.
- Stock, Chester.—Canid and Proboscidean Remains from the Ricardo Deposits, Mohave Desert, California.
- Stock, Chester.—A Tooth of *Hipparion mohavense* from the Puente Formation, California.
- Maxson, John H. *Merychippus isonesus* (Cope) from the Later Tertiary of the Crooked River Basin, Oregon.
- No. 396. St. John, Charles E., Charlotte E. Moore, Louise M. Ware, Edward F. Adams, and Harold D. Babcock. Revision of Rowland's Preliminary Table of Solar Spectrum Wave-Lengths with an Extension to the Present Limit of the Infra-Red. Quarto, xxi+328 pp.

CARNEGIE INSTITUTION OF WASHINGTON

BIBLIOGRAPHY OF CONTRIBUTIONS TO KNOWLEDGE RELATING TO WORK OF INVESTIGATORS, ASSOCIATES AND COLLABORATORS ISSUED THROUGH CHANNELS OTHER THAN THE PUBLICATIONS OF THE CARNEGIE INSTITUTION OF WASHINGTON.

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REPORT OF THE EXECUTIVE COMMITTEE

REPORT OF THE EXECUTIVE COMMITTEE

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1928.

During this year the Executive Committee held seven meetings, printed reports of which have been mailed to each Trustee.

Upon adjournment of the meeting of the Board of Trustees of December 9, 1927, the members of the Executive Committee met and organized by the election of Mr. Root as Chairman for 1928.

A full statement of the finances and work of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. A detailed estimate of expenditures for the succeeding year is also contained in the report of the President, and has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted herewith.

The Board of Trustees, at its meeting of December 9, 1927, appointed Messrs. Leslie, Banks & Company to audit the accounts of the Institution for the fiscal year ending October 31, 1928. The report of the Auditor, including a balance-sheet showing assets and liabilities of the Institution on October 31, 1928, is submitted as a part of the report of the Executive Committee.

There is also submitted a statement of receipts and disbursements since the organization of the Institution on January 28, 1902.

No vacancies exist among the officers of the Board or in the membership of any of its Committees.

ELIHU ROOT, *Chairman*
JOHN J. CARTY
W. CAMERON FORBES
JOHN C. MERRIAM
WM. BARCLAY PARSONS
STEWART PATON
HENRY S. PRITCHETT
GEORGE W. WICKERSHAM

November 19, 1928.

CARNEGIE INSTITUTION OF WASHINGTON

Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1928

RECEIPTS		DISBURSEMENTS	
<i>Interest</i>		<i>Investment</i> .....	..... (a) \$36,277,088.59
Endowment	\$25,124,720.05		
Reserve Fund	1,828,691.99		
Colburn Fund	63,457.52	<i>Pension Fund</i>	313,092.70
Harriman Fund	106,000.		
Pension Fund	75,112.37		
Insurance Fund	219,868.56	<i>Insurance</i>	38,761.80
Sp'l Emer. Reserve Fund	3,945.73		
	\$27,421,796.22	<i>Sp'l Emer. Reserve Fund</i>	5.16
<i>Colburn Fund</i>	52,015.74		
		<i>General Contingent Fund</i>	35,621.57
<i>Sales of Publications</i>			
Index Medicus	110,018.30		
Year Book	1,492.48		
Miscellaneous	163,349.88	<i>Grants</i>	
		Large	\$17,823,807.20
		Minor	3,454,320.87
<i>Reversions</i>			21,278,128.07
<i>Pension Fund</i>		<i>Publication</i>	1,574,968.26
<i>Redemption and Sale of Bonds</i>	25,167.70	<i>National Research Council</i>	150,000.
	29,749,853.62		
<i>Carnegie Corporation of New York</i>		<i>Administration</i>	1,385,781.94
C. I. of W	3,174,135.42		
Nat'l R. C.	150,000.		
Special	289,000.		
	3,613,135.42		61,053,448.09
<i>Miscellaneous</i>			
Sale of paper	6,681.01		
Insurance	6,861.51	<i>Cash in Banks</i>	448,770.20
			61,502,218.29

(a) Including Administration Building, \$309,915.69, and Collection Charges.

REPORT OF AUDITORS

NEW YORK, *December 1, 1928.*

TO THE BOARD OF TRUSTEES:

*Carnegie Institution of Washington,
Washington, D. C.*

DEAR SIRs: We have audited the accounts of the Carnegie Institution of Washington for the fiscal year ended October 31, 1928.

All Securities were verified by inspection and are shown at cost on the Balance Sheet. The Cash in Banks was confirmed by the Depositories and the Cash on Hand by actual count.

All income from Investments has been accounted for and the appropriations and allotments checked with certified copies of the minutes of the Institution.

Real Estate and Equipment are carried at cost.

The books of the various departments are audited by the Bursar, and we have included his figures in the annexed Balance Sheet without examination by us.

We hereby certify that, in our opinion, the Balance Sheet annexed hereto correctly states the financial condition of the Institution at October 31, 1928.

LESLIE, BANKS & COMPANY,
Accountants.

Copies of the Financial Statement, certified by the auditor in the above report, follow on pages 44 to 49.

Balance Sheet, October 31, 1928

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REPORT OF AUDITORS

RECEIPTS		DISBURSEMENTS	
<i>Interest from</i>		<i>Investment</i>	
Endowment		Securities	\$25,748,491.08
Reserve Fund.....	\$1,496,737.48	Accrued Interest.....	261,947.11
Colburn Fund.....	161,464.02		
Harriman Fund.....	5,415.	<i>Pension Fund</i>	
Pension Fund.....	12,000.		\$26,010,438.19
Insurance Fund.....	12,120.67		41,935.32
Sp'l. Emer. Reserve Fund.....	25,077.18	<i>Insurance Fund</i>	
	2,678.14		4,629.95
<i>Sales of Publications</i>		<i>Sp'l. Emer. Reserve Fund</i>	5.16
Index Medicus.....	\$887.85		
Year Book.....	87.80	<i>General Contingent Fund</i>	6,829.01
Miscellaneous Books.....	9,948.60		
<i>Reverments</i>		<i>Grants</i>	
Large Grants.....	23,555.62	Large	1,208,942.20
Minor Grants.....	2,684.93	Minor	227,909.32
Publication	1,495.36		
Administration	635.71	<i>Publication</i>	
Unappropriated Fund.....	2,632.20	General Publication.....	66,000.99
Gen. Contingent Fund.....	140.60	Catalogues, etc.....	1,097.87
		Shipping Expenses.....	7,900.80
		Division of Publications.....	18,571.36
<i>Pension Fund</i>	31,144.42		93,571.02
	2,007.50	<i>Administration</i>	
<i>Redemption and Sale of Securities</i>		Trustees	2,952.42
	24,843,191.68	Executive Committee.....	3,441.26
<i>Carnegie Corp. of N. Y.</i>	1,223,437.50	Salaries	46,727.50
		Surety post. tel. & tel.....	2,236.19
		Printing	2,411.31
		Office expenses.....	3,420.73
		Equipment	18.68
		Building maintenance.....	9,792.40
	27,826,197.84	Lectures and Exhibits.....	2,052.11
			73,052.60
<i>Balance, October 31, 1927</i>	289,885.13		27,667,312.77
	28,116,082.97	<i>Cash in Banks</i>	448,770.20
			28,116,082.97

CARNEGIE INSTITUTION OF WASHINGTON

Schedule of Securities

Par Value Represented in Thousands							Aggregate— Par or Nominal Value	Description	Ma- tur- ity	Total Cost or Value at Date Acquired
Endow- ment	Col- burn	Harri- man	Re- serve	Insur- ance	Pen- sion	Spl. Em. Re. Fd.				
\$500							\$500,000	<i>Railways:</i>		
50							50,000	A. T. & S. Fe. 1st & ref. 4½s	1962	\$498,750.
43							43,000	" " " pref. stock		52,125.
				\$50			50,000	" " " conv. 4s	1955	39,022.50
50			\$100				150,000	A. T. and S. Fe gen. 4s	1995	50,056.25
200							200,000	B. and O. R. R. gen. and ref. 5s	1995	153,625.
100							100,000	Boston & Maine 1st 5s	1967	195,812.50
			40		\$10		50,000	Canadian Pac. Col. Trust 4½s	1946	98,125.
175							175,000	Canada So. con. 5s	1962	49,021.50
			50				50,000	Ches. & Ohio gen. 4½s	1992	174,062.50
			150	30			180,000	Cent. Pac. Ry. 1st ref. 4s	1949	48,250.
		\$200					200,000	C. B. & Q. R. R. gen. 4s	1958	169,501.25
35							35,000	C. B. and Q. Ill. Div. 4s	1949	200,000.
110							110,000	C. M. St. P. & P. 5s	1975	31,853.50
140							140,000	Chi., Ind. & L. 1st & gen. 5s	1966	111,693.75
214	\$4		15	1			234,000	Chi. M. St. P. & P. conv. adj. 5s	2000	127,414.50
			120				120,000	C. M. and St. P. Ry. gen. 4½s	1989	227,162.50
200							200,000	Chi. and N. W. Ry. gen. 3½s	1987	100,300.
300							300,000	Chi. & N. W. R. R. gen. 4½s	1987	210,000.
25			75				100,000	Chi., R. I. & P. Ry. 4½s	1952	282,362.50
100							100,000	Chi. U. Station 6½s	1963	114,266.50
								Clev. C.C. & St. L. Ry., ref. and		
25	10		5		10		50,000	imp. 4½s	1977	99,272.50
50							50,000	Clev. U. Term. 1st sink. 5½s	1972	51,612.50
500							500,000	Col. & Sou. Ry. ref. & ext. 4½s	1935	48,000.
380							380,000	Elgin J. & E. Ry. Eq. 5s		500,000.
300							300,000	" " " 6s		360,000.
			48	21			69,000	Erie R. R. gen. 4s	1996	242,937.50
125							125,000	Gt. Nor. 1st ref. 4½s	1961	69,053.25
165							165,000	Gt. Nor. Ry. gen. 4½s	1977	122,656.25
247							247,000	" " " 5s	1973	174,712.50
			100	21			121,000	Ill. Cent. R. R. Joint 5s	1963	257,172.75
350			50				400,000	Ill. Cent. R. R. ref. 4s	1955	108,677.50
200							200,000	Kan. City Term. 1st 4s	1960	359,457.50
325							325,000	Kan. City, F. S. & M. Ry. ref. 4s	1936	187,250.
100							100,000	Lehigh & L. E. 4½s	1957	331,568.30
			50				50,000	Lehigh V. H. Term. Ry. 1st 5s	1954	104,750.
150							150,000	Long Island ref. 4s	1949	48,285.
100			50	25	25		200,000	Louisville & N. R. R. 1st & ref. 4½s	2003	150,000.
150			15	10		\$18	193,000	Mo. Kan. & T. 1st 4s	1990	165,206.26
160							150,000	Mo. Pac. R. R. Co. 1st and ref. 5s	1977	193,662.50
								Mobile and O. R. R., ref. and imp.		
175							175,000	4½s	1977	145,750.
			50				50,000	N. Y. Cent. R. R. ref. & imp. 5s	2013	186,906.25
70							70,000	N. Y. W. and Boston 1st 4½s	1946	49,187.50
			95	5			100,000	Norfolk & W. Joint 4s	1941	64,925.
			50				50,000	Nor. Pac. ref. and imp. 6s	2047	102,187.50
			2	25	20		51,000	" " " gen. lien 3s	2047	33,101.25
150	10		50	25	15		250,000	Ore. Short Line con. 5s	1946	49,883.25
	50		30				80,000	Ore. Wash. R. & N. 1st. ref. 4s	1961	221,327.50
			101	24			125,000	Pa. R. R. Co. gen. 4½s	1965	80,900.
100							100,000	" " " con. 4½s	1960	130,703.13
	42						42,000	Pitts. C. C. & St. L. 5s	1975	99,637.50
			100				100,000	Pitts. Shawmut & Nor. 4s	1952	4,200.
							100,000	So. Pac. 1st ref. 4s	1955	92,148.75
							100,000	So. Pac. S. F. Ter. 4s	1950	100,000.
275			50	25			350,000	So. Rwy. Co. 1st con. 5s	1994	382,531.25
45							45,000	St. Paul Union D. 1st & ref. 5s	1972	48,150.
200							200,000	St. Louis-S. F., prior lien 4s	1950	182,400.
100							100,000	Term. R. R. Assn. 4s	1953	85,538.
210							210,000	Texas & Pac. R. R., gen. and ref. 5s	1977	213,882.50
2,084							2,084,000	Union R. R. deb. 6s	1946	2,084,000.
			140				140,000	Union Pac. 1st lien and ref. 4s	2008	128,722.50
150							150,000	Union Pac. R. R. 4s	1968	133,031.25
40							40,000	" " " pref. stock		33,415.
200							200,000	Va. Ry. Co. 1st 5s	1962	206,535.50
200							200,000	Wabash Ry., ref. and gen. 5s	1976	203,250.
175							175,000	Western Md. R. R. 1st 4s	1952	141,287.50
55							55,000	Wash. Term. Co. 1st 3½s	1945	47,778.75
9,768	120	300	1,536	262	80	18	12,084,000	Railway Sub-Total		11,741,958.94

REPORT OF AUDITORS

Schedule of Securities—Continued

Par Value Represented in Thousands							Aggregate— Par or Nominal Value	Description	Ma- tur- ity	Total Cost or Value at Date Acquired
Endow- ment	Col- burn	Harri- man	Re- serve	Insur- ance	Pen- sion	Spl. Em. Re. Fd.				
\$150			\$50				\$200,000	<i>Public Utility:</i>		
100							100,000	Ala. Power Co. 1st ref. 5s	1951	\$197,250.
100			47	\$53	\$25		225,000	Ala. Power Co. 1st & ref. 5s	1968	99,656.25
300							300,000	Am. Tel. & Tel. sink. deb. 5½s	1943	233,646.25
300							300,000	Am. Tel. & Tel. deb. 5s	1960	308,000.
250			50				300,000	Apl. E. P. Co. 1st ref. 5s	1956	296,125.
250							300,000	Ark. P. & L. Co. 5s	1956	292,312.50
25							250,000	Bell Tel. Co. of Canada 1st 5s	1955	257,656.25
300							25,000	" " " " " "	1957	25,750.
300							300,000	Birmingham E. Co., 1st ref. 4½s	1968	283,056.25
300							300,000	Car. P. & L. Co. ref. 5s	1956	302,298.75
100			25				125,000	Cedar R. Mfg. & P. Co. 1st sink. 5s	1953	123,669.54
300							300,000	Cin. Gas. & E. 1st 4s	1968	268,105.75
300							300,000	Col. Gas and Elec., deb. 5s	1952	303,125.
255							255,000	Columbus Rwy. P. & L. 4½s	1957	243,787.50
40							40,000	Comm. Edison 1st col. 5s	1954	42,000.
115							115,000	" " " " " "	1956	114,193.75
100							100,000	Cons. Gas. Co. Cum. pref. stock.		99,225.
65							65,000	Cons. P. Co. 1st 5s	1952	67,450.
			25	25			50,000	Consumers P. Co. 1st ref. 5s	1936	47,691.
			100				100,000	Detroit Edison gen. ref. 5s	1955	99,942.50
150							150,000	Detroit Edison gen. ref. 5s	1962	155,825.
300						\$25	325,000	Ga. Power Co. 1st ref. 5s	1967	320,112.50
300							300,000	Gatineau Power, 1st 5s	1956	298,750.
15							15,000	Gulf States Util. Co. 1st 5s	1956	14,850.
100							100,000	Idaho P. Co. 5s	1947	100,750.
200							200,000	Illinois P. & L., 1st & ref. 5s	1956	196,750.
200							200,000	Indianapolis P. & L. 1st 5s	1957	198,806.25
200							200,000	Ind. & Mich. Elec. Corp., 1st ref. 5s	1955	202,182.50
300							300,000	Inter. Tel. & Tel. deb. 4½s	1952	283,250.
			280				280,000	Int. Rap. Trans. ref. 5s	1966	276,701.
			27	25	20		72,000	Kan. City P. & L. 5s	1952	71,955.25
40							40,000	Louisville G. & L. 1st & ref. 5s	1952	41,368.75
300							300,000	Memphis P. & L. 1st & ref. 4½s	1978	279,250.
95							95,000	Milwaukee E. R. & L. ref. & 1st 5s	1961	96,393.75
100							100,000	Minn. P. & L. 1st & ref. 4½s	1978	92,156.25
110							110,000	Narragansett E. Co. 1st 5s	1957	109,787.50
			30	12	10		52,000	N. Eng. Tel. & Tel. 5s	1952	51,748.
100							100,000	New Orleans Pub. S. 5s	1955	99,200.
			50				50,000	N. Y. Edison 1st ref. 6½s	1941	55,573.75
			18		24		42,000	N. Y. Gas. E. L. H. P. pur. mon. 4s	1949	34,620.50
300							300,000	New York P. & L., 1st 4½s	1967	286,125.
60							60,000	Niagara Falls P. 1st & con. 5s	1959	61,800.
270							270,000	No. Ind. Pub. S., 1st ref. 5s	1966	275,450.
100							100,000	Nor. States P. 1st ref. 5s	1941	99,709.50
300							300,000	Ohio Power Co., 1st and ref. 4½s	1956	280,181.25
175							175,000	Okla. G. & E. 1st 5s	1950	175,250.
150			50				200,000	Pac. G. & E. Co. gen. & ref. 5s	1942	197,185.53
25							25,000	Pac. Tel. & Tel. 5s	1952	26,187.50
45							45,000	Penn. P. & L. 1st & ref. 5s	1952	46,125.
31							31,000	Penn. W. & P. 1st ref. 4½s	1968	30,147.50
50							50,000	Peoples G. L. & C. 1st & ref. 5s	1976	51,250.
425							425,000	Phila. E. Co. 1st & ref. 4½s	1967	427,106.25
70							70,000	Pub. Serv. of Nor. Ill. 1st & ref. 5s	1956	71,750.
150							150,000	" " " " " "	1967	150,375.
200							200,000	San Joaquin L. & P. Corp., ref. 5s	1957	201,968.75
300							300,000	Shawinigan W. & P. 1st & coll. 4½s	1967	286,212.50
			50				50,000	So. Bell Tel. & Tel. 1st sink. 5s	1941	47,687.50
300							300,000	So. Calif. Edison Co., ref. 5s	1952	307,457.50
			50				50,000	So. Calif. Tel. Co. 1st ref. sink. 5s	1947	46,000.
100							100,000	Tenn. E. & P. 1st and ref. 5s	1956	100,912.50
190			50				240,000	Tex. P. & L. Co. ref. 5s	1956	236,262.50
175			10	15			200,000	Utah L. & T. Co. ref. 5s	1944	196,553.
250			50				300,000	Va. E. & P. Co. 1st and ref. 5s	1955	301,606.25
9,526			962	130	79	25	10,722,000	Public Utility Sub-Total		10,593,175.33

Schedule of Securities—Continued

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REPORT OF AUDITORS

Real Estate and Equipment, Original Cost

<i>Administration (October 31, 1928)</i>		
Building, site, and equipment.....		\$341,404.17
<i>Division of Plant Biology (September 30, 1928)</i>		
Buildings and grounds.....	\$58,074.56	
Laboratory and library.....	54,371.89	
Operating appliances.....	13,565.20	
		<hr/> 126,011.65
<i>Department of Embryology (September 30, 1928)</i>		
Library	2,052.88	
Laboratory	9,797.11	
Administration	4,701.21	
		<hr/> 16,551.20
<i>Department of Genetics (September 30, 1928)</i>		
Buildings, grounds, field.....	281,615.57	
Operating	22,174.97	
Laboratory apparatus.....	15,478.67	
Library	30,116.17	
Archives	45,488.90	
		<hr/> *394,874.28
<i>Geophysical Laboratory (September 30, 1928)</i>		
Building, library, operating appliances.....	202,201.79	
Laboratory apparatus.....	116,073.95	
Shop equipment.....	13,910.27	
		<hr/> 332,186.01
<i>Department of Historical Research (September 30, 1928)</i>		
Office	3,763.06	
Library	5,379.54	
		<hr/> 9,142.60
<i>Department of Marine Biology (September 30, 1922)</i>		
Vessels	30,930.43	
Buildings, docks, furniture, and library.....	12,130.86	
Apparatus and instruments.....	9,322.55	
		<hr/> 52,383.84
<i>Department of Meridian Astrometry (September 30, 1928)</i>		
Apparatus and instruments.....	3,746.84	
Operating	4,747.56	
		<hr/> 8,494.40
<i>Nutrition Laboratory (September 30, 1928)</i>		
Building, office, and shop.....	127,449.88	
Laboratory apparatus.....	31,080.63	
		<hr/> 158,530.51
<i>Mount Wilson Observatory (August 31, 1928)</i>		
Buildings, grounds, road, and telephone line.....	199,324.64	
Shop equipment.....	44,423.27	
Instruments	583,522.75	
Furniture and operating appliances.....	182,102.90	
Hooker 100-inch reflector.....	600,159.86	
		<hr/> 1,609,533.42
<i>Department of Terrestrial Magnetism (September 30, 1928)</i>		
Building, site, and office.....	211,711.16	
Vessel and survey equipment.....	214,802.34	
Instruments, laboratory, and shop equipment.....	139,642.41	
		<hr/> 566,155.91
		<hr/> <hr/> 3,615,267.99

* Including Harriman Fund property in the amount of \$183,671.75 shown as a separate item on the Balance Sheet.

REPORTS ON INVESTIGATIONS AND PROJECTS

The following reports and abstracts of reports show the progress of investigations carried on during the year ending June 30, 1928, including not only those recently authorized, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

DEPARTMENT OF EMBRYOLOGY¹

GEORGE L. STREETER, DIRECTOR

When a program for the study of human development was visioned by the Trustees of the Carnegie Institution of Washington and the late Professor Mall, who was entrusted with its organization, the decision had to be made between a detached institution as against one blended with related activities already in existence. The wisdom of their choice of the latter policy becomes more and more evident as the years pass. Multiple contacts are not necessarily detrimental to the growth of an effective individuality; they, on the contrary, provide the opportunity for its unlimited development. This policy has made possible the establishment of close associations with other Departments of the Carnegie Institution and with various laboratories of the Johns Hopkins University and Medical School and particularly the Department of Anatomy, in the investigations and personnel of which our interests have been inextricably blended from the very outset. Similar relations have developed between us and embryological laboratories in other universities, through which means cooperative endeavors are being carried on that could not otherwise be accomplished, and such extramural contacts may be expected to increase as opportunity offers. Another type of contact arises from our natural relation to the general medical profession. Each year about 600 embryological specimens are received for examination and diagnosis. By seeing a large number of such specimens we have obtained experience and data that enable us to give expert opinion on such matters as the determination of age, sex, race, anomalous development, pathological conditions and, to some extent, the cause of the abortion or defective condition when such occur. In performing this service for the physician we, in return, receive valuable clinical information from him. We have learned that the abnormal specimen frequently reveals important facts regarding normal development, and of course it is only through the physician that we can obtain the material on which our human studies are based.

The researches that have been completed during the past year are described in the following pages. It will be noted that they fall in certain groups. Under the heading of general embryology an account is given of the organization of the mammalian egg and its differentiation into primitive tissues, the significance of the trophoblast, studies on the origin of the human heart, the development of the neuromuscular spindles, nasal cartilages and volar pads. Under living tissues is included a group of important investigations on the cell as a unit. Among these are observations on the phenomenon of locomotion as exhibited by the white blood cell and further experiments and observations on certain sarcoma cells that bring us nearer to an understanding of the factors involved in that unfortunately prevalent type of abnormal growth. Under experimental embryology are described studies in organogenesis and the production of protozoan monsters. Under

¹ Address: Wolfe and Madison Streets, Baltimore, Maryland.

the title of organs and mechanism of reproduction are grouped a series of studies on the ovary, the function of the corpus luteum, the lymphatics of the fallopian tube and character of the tubo-uterine junction, and the cellular content of the vaginal secretions. Though it is still of modest proportions and in an experimental stage, our monkey colony is beginning to yield results. Two outstanding studies are reported, namely, the duration and symptoms of pregnancy in the *Macacus rhesus* and the description of the phenomenon of parturition, an instinctive act of importance to the student of animal behavior. A number of studies of implantation in various animals are grouped under the heading of placentation. The investigations on the nervous system include studies on the correlation between structural and functional development of the cortex of the brain, also the correlation between reflex activity and myelination, studies on muscle innervation, muscle tonus and a review of the problem of control of posture, all of these being the necessary foundations for the understanding of the problems of reflex behavior. Finally there are two studies on growth in higher primates and man and a series of studies of the anatomy of various adult organs with developmental and comparative anatomical bearings.

GENERAL EMBRYOLOGY AND ORGANOGENESIS

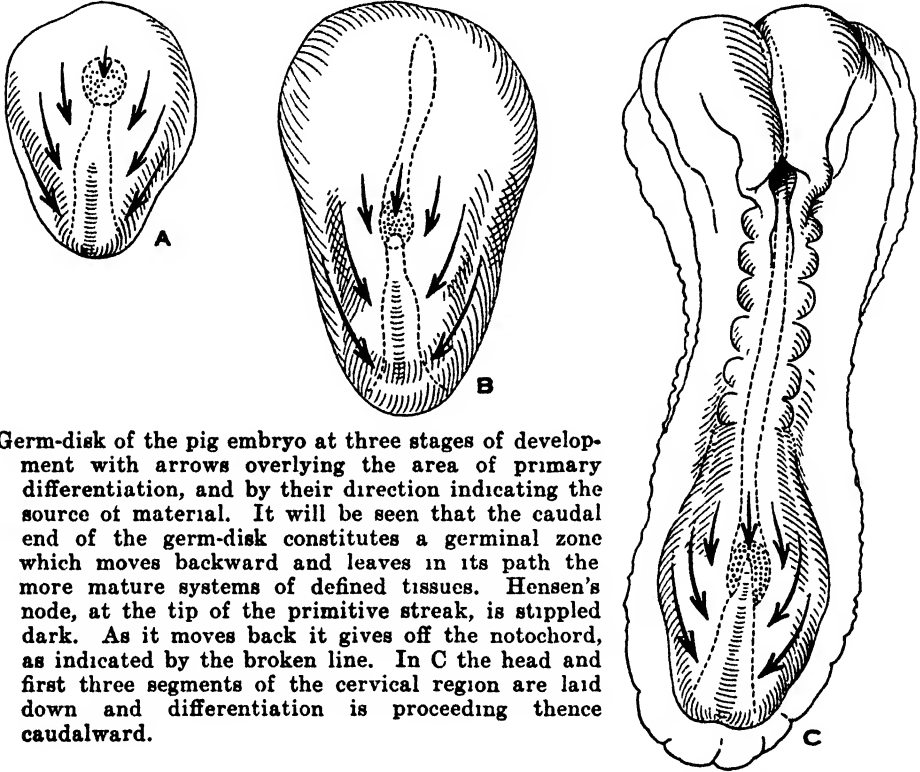
ORIGIN OF THE MESOBLAST

For the very early periods in development it has been necessary to supplement what may be learned from human embryos with studies of other higher mammalian forms where abundant material can be obtained and in all desired stages. It has been found that the pig meets these requirements best, and for the past few years we have been devoting considerable attention to this chosen form. As part of the laboratory program I have studied the development of the mesoblast, starting from its first appearance and following its spread and differentiation until the first few somite-pairs are marked off. For the study of the mesoblast and notochord one could hardly have selected a better representative of the higher mammals than the pig, for in that animal these tissues in their earliest stages stand out with marked distinctness and simplicity.

From observations made on this material it is evident that the first act of the germ-disk comprises an active cell proliferation at what proves to be its caudal pole and the detachment of some of these cells ventrally to form the first elements of the mesoblast. It is to be noted that the blastocyst is primarily bilaminar and that ectoderm and entoderm constitute two contraposed membranes that maintain their entity and separateness throughout all subsequent development. If we are to speak of primary germ-layers the term should be limited to them. The mesoblast is clearly a derivative of the ectoderm and therefore in logical classification must take the position of a subhead under it. In a strict sense the mesoblast is not a primary germ-layer.

The proliferation and shedding of mesoblast cells by the germ-disk ectoderm at its caudal pole produces an appearance which in later phases is known as the primitive streak, and this phenomenon of a germinal caudal pole persists throughout development until the entire body is finally laid

down. A similarly derived but independent structure known as the notochord arises a little later at the front end of the primitive streak, and the special area of proliferative ectoderm of which it is the product is called Hensen's node. The caudal region of the disk and body of the embryo is made up jointly of the primitive streak and Hensen's node and constitutes the growing or rather differentiative end resulting in our development in the cranio-caudal direction as shown in the accompanying figure. This



Germ-disk of the pig embryo at three stages of development with arrows overlying the area of primary differentiation, and by their direction indicating the source of material. It will be seen that the caudal end of the germ-disk constitutes a germinal zone which moves backward and leaves in its path the more mature systems of defined tissues. Hensen's node, at the tip of the primitive streak, is stippled dark. As it moves back it gives off the notochord, as indicated by the broken line. In C the head and first three segments of the cervical region are laid down and differentiation is proceeding thence caudalward.

caudal germinal pole is to be regarded as a persistence of the proliferative germ-disk phase, a focus of differentiation of notochord and mesoblast. These two structures, at the time they are differentiated into their primary state, are deposited in a more or less final position relative to the body as a whole. Later, in their histogenesis, they undergo further or secondary differentiation in loco, and one can then observe the gradual disintegration of the mesoblast into such various tissues as the blood-vascular system, mesothelial membranes, muscle, cartilage, bone and ordinary connective tissue. An account of the observations made on the earlier phases of these phenomena has been completed during the past year and has appeared in volume XIX of the Contributions to Embryology.

TROPHOBLAST CELLS

In a preceding paragraph attention has been called to the inadequacy for mammals of the prevalent usage of deriving the embryo from three primary germ-layers, a custom owing its popularity to its apparent appropriateness in the ubiquitous chick. Still greater difficulties arise if the concept of three primary germ-layers is forced back into the period of the

beginning segmentation cavity and earliest blastocyst. One finds in the segmenting egg that the distinction between formative and non-formative cells is more fundamental than such a characteristic as forming the outer layer of the egg, *i. e.* ectoderm. The topographic likeness of trophoblastic ectoderm and embryonic ectoderm is far less significant than their potential difference. As we become better acquainted with the mammalian blastocyst it becomes evident that there is still much to learn regarding the process of its organization, but it is already evident that it will be necessary to express the concept with other terms than the three primary germ-layers.

Dr. C. H. Heuser and I have studied the segmentation of the pig ovum, using serial sections of timed eggs, many of which were reconstructed with wax-plate models. We found that trophoblast cells become histologically differentiated at about the 16-cell stage which is on the fifth day after insemination. Coincident with this, fluid begins to accumulate in lakelets that fuse to form the segmentation cavity and this is assumed to be an expression of the functioning of the trophoblast. The trophoblast cells are the most precocious cells of the egg and soon constitute a membrane completely enclosing it. The inner cell mass is the residual part of the egg and for a time retains its primitive character. After the last trophoblast cells have separated from it, there are left those that will form the germ-disk and its underlying entoderm. This completes the division of the egg into cells that will form the embryo germ-disk and entoderm as against those that will constitute its implanting mechanism (trophoblast), which are permanently separate structures. These studies are now in the process of preparation for publication.

ORIGIN OF THE HUMAN HEART

When one speaks of the laying down of the primordium of an organ it is inferred that that organ in its primitive state can then be recognized structurally as differing from surrounding tissues and organs. The reservation must be kept in mind that there is much evidence for believing that some organs are determined and certain cells allotted to that purpose long before there is any such visible distinction between them and other cells. During the third week of development of the human embryo one finds our chief organ-systems being marked off in their primary form. One can then begin to recognize the landmarks of the brain and spinal cord, the alimentary tract is separated off from the yolk-vesicle, the respiratory system and the liver are just emerging, the body-somites are being rapidly laid down and most conspicuous of all are the first great vessels and the beginning heart. This third week is one of outstanding interest to the student of organogenesis. Until Dr. C. L. Davis began his work very little was known regarding this early period in the history of the human heart. He has recently brought together his observations which have accumulated over a period of several years and include the careful study of this organ in a close series of stages ranging from the time of appearance of the first pair of somites to embryos of 20 somite-pairs and in which the anterior neuropore has just closed. He describes the origin of the cardiogenic plate from which the muscular wall of the heart is formed, and traces its modeling

into the main parts of the heart. He also describes and pictures the angio-blasts and the primitive endothelial cardiac plexus and follows the transformation of the latter into the endocardium or lining membrane of the several parts of the heart. All of this had been known only roughly and in a diagrammatic way. Dr. Davis now has substituted actual stages. It is of interest to note that he finds that both the myocardium and endocardium are derived from bilateral primordia, though not completely separated. The parts forming the atria are definitely paired and their bilateral identity is maintained, differing in this respect from the ventricular and bulbar regions. Dr. Davis effectually disposes of the "ventral mesocardium" which has long been treasured by the diagrammers.

EMBRYOLOGY OF THE NEUROMUSCULAR SPINDLE

The study of the histogenesis of the neuromuscular spindle in pig fetuses has been completed by Dr. F. Cuajunco and has appeared in the *Contributions to Embryology*. For purposes of preciseness and for simplification of the problem, his attention was limited to the biceps of this one animal, which could be obtained in abundant quantity in all stages from 20 to 250 mm. crown-rump length. Apparently, this sense organ varies in form in different animals and even in different muscles. The material was prepared by a silver impregnation method that rendered visible the structure of all the components of the spindle. This was not accomplished without some difficulty and required many experimental trials and modifications in technique, all of which are duly recorded by Dr. Cuajunco for the benefit of subsequent investigators.

At the outset the particular muscle-fibers that are to be combined in a spindle undergo a differentiation resembling that of ordinary muscle-fibers and they can first be recognized at the 30-mm. stage, their recognition then being dependent on the presence of a characteristic nerve ending. In fetuses 40 to 45 mm. long a definite plexus of nerves can be recognized around the young muscle-fibers, and the nuclei of the muscle-fibers become aggregated in a single row in the center of each fiber. At 50 mm. the muscle-fibers become grouped in spindles and the nuclei in the future equatorial region increase in number, forming a compact cluster that fills up the whole segment of the muscle-fiber. At 80 mm. the nerve plexus consists of a complicated net of delicate nerve-fibrils which begin to exhibit tiny knots and ringlets at their points of intersection, and the muscle-fibers of the spindle begin to show transverse striations, which differ from those of the extrafusal fibers in being wider and in taking a deeper stain in the dark bands. The capsule of the spindle can be recognized at 80 mm., but it does not become definitely cellular until the 100 to 110-mm. stage is reached. The periaxial lymph space makes its appearance in fetal pigs of 150 mm. as a slit-like separation between the capsule and the axial bundle, and at the same time the spinal nerves begin to acquire their medullary sheaths.

Beyond the stage of 150 mm. further differentiation of the spindles is characterized by the development of enlargements at the intersections of the nerve-fibrils and the extension of irregular processes, resulting in multi-

form and complex endings in contact with the surface of the muscle-fibers enclosed in the spindle. Among these older stages Dr. Cuajunco recognizes delicate fibers entering the spindles and blending with the non-medullated terminals of the medullated fibers. These he regards as sympathetic, but this must await better proof. Distinctly separate nerve branches can occasionally be seen supplying a neuromuscular bundle.

A muscle-fiber belonging to a spindle is uniform throughout its whole length, save for the alterations in the equatorial region and at the ends where modification is necessary for attachment. Beyond the ends of the capsule, the polar innervation and the character of the polar fibers are continued in the extra-capsular portion of the neuromuscular bundle. Dr. Cuajunco obtained good photographs of representative stages of these structures which will be of value to those who can not see his original preparations.

ONTOGENY AND PHYLOGENY OF NASAL CARTILAGES

Dr. I. C. Wen has studied the development and comparative anatomy of the nasal cartilages in a series of prosimian, platyrrhine, and catarrhine monkeys and also in orang and man. A preliminary account of his interesting observations has been published and it is evident that they will be of value to the physical anthropologist in the interpretation of racial specializations in the human nose.

VOLAR PADS OF THE HUMAN EMBRYO

Another study that will concern the physical anthropologist as well as the embryologist is that of Dr. Cummins of Tulane University, who during the past summer was a guest in this laboratory. As an extension of his well-known study of the epidermal ridges, he has made a series of observations on the surface topography of the hands and feet of a series of human embryos ranging from 17 mm. to 341 mm., sitting height. His attention was given particularly to the volar pads, otherwise known as touch- or walking-pads. He finds that they have definite morphological identities which are most pronounced in embryos smaller than 40 mm. With advance in development they lose their distinct outlines, become less prominent and in some instances fuse with other pads. This regression begins in the hand at about the 60-mm. stage and in the foot at about the 100-mm. stage. A full account of Dr. Cummins' observations is in preparation for publication in volume XX of the Contributions to Embryology.

STUDIES OF LIVING TISSUES

LOCOMOTION OF THE WHITE BLOOD CELL

A series of observations has been made by Dr. Warren H. Lewis on the structural features that are associated with the locomotion of the cell. As an actively migrating cell he chose the neutrophilic leucocyte, which can be observed in plasma cultures of the buffy coat or in spreads of deep fascia. It was preparations of the latter that were chiefly used by him and that enabled him to determine the modifications of the cells during this interesting phenomenon. He finds that during migration the cells are rather fan-shaped, broad at the anterior end and tapering to a narrower

posterior end. Tufts of thin, wavy, film-like pseudopodia project from the anterior ends, whereas the posterior ends are either pointed, blunt, or knob-like and frequently terminate in several long slender processes. From these characteristics their direction of migration can be at once recognized.

Contraction waves can be seen starting at the anterior end and moving in a few seconds backward along the entire length of the cell. In this process, as the wave reaches the posterior end, there is often a knob of cytoplasm partly pinched off from the rest of the cell, but these polypoid bits always ultimately flow back into the cell. The long slender posterior processes are produced by the stretching out of adherent portions as the main mass of the cell moves forward. These processes finally break or else lose their attachments and are drawn back into the cell body.

The contractile part of the cell seemed to be the thin ectoplasm which, however, was not sharply separated from the more fluid endoplasm. The endoplasm is most fluid, as evidenced by Brownian motion, at the base of the pseudopodial tuft. As the contraction wave spreads from here backward, the granules of the compressed endoplasm can be seen streaming forward. The nucleus is variously displaced in this process. When the cell comes to rest it rounds up and the pseudopodial tuft disappears. It is important to note that such cells do not possess a fixed anterior end. A new anterior end, with a new tuft of pseudopodia, may start out anywhere along the side, and thereon the contraction waves are initiated from that point and no trace is left of the old anterior end. Dr. Lewis obtained good photographic single records of these phenomena. A further advance, however, may be expected when moving picture films of these cells become available for study.

SPINDLE AND MONONUCLEAR CELLS IN RAT SARCOMA

In order to determine as far as possible the cytological and cultural peculiarities of the two types of cells that emigrate in cultures of this tumor, Dr. W. H. Lewis has made a careful study of explants of the spindle-cell rat sarcoma (Walker sarcoma I).

In his preliminary studies, made in association with Dr. Brüda and Mr. Gey, it became apparent that the migratory cells presented appearances that varied under different conditions. His final conclusions are that there are two distinct types of emigrating cells. One of these, the mononuclear or macrophage, differs in no discernible way from those normally present in the body and those obtained from cultures of the whole blood and the buffy coat of normal animals. The other cell, the spindle cell, differs somewhat from normal ones in the character of its nucleus and cytoplasm. Apparently the latter are mutant cells, either modified permanently, due to a virus or other agent, or temporarily modified, due to the continued presence of the virus, the effective agent, or condition of environment. In the early studies of tumor cultures it was supposed that one or the other of these two types of cells was the "tumor" cell. Pure cultures were obtained of each with the view to determining which was the guilty cell. When it was later found that cell-free blood plasma of sarcomatous chickens was able to produce tumors, it became apparent that the "virus" was the

important thing rather than the cell which might or might not harbor it. Whether this applies to mammalian as well as fowl tumors can not be said, as up to the present no one has been able to demonstrate conclusively the existence of a virus for mammalian sarcomas.

INACTIVATION OF CHICKEN-TUMOR VIRUS

In our report for last year an account was given of how it was discovered by Mrs. M. R. Lewis and Dr. H. B. Andervont that the presence of carmine inactivated chicken-tumor virus and how it was further found to be the aluminium and calcium components rather than the dye principle that was the effective agent. This has led these investigators to conduct a series of experiments with various calcium and aluminium salts. As for calcium, they have found that calcium oxide, calcium monobasic phosphate, and calcium hexose phosphate, in as small amounts as 0.5, 0.75, and 1 per cent, respectively, when added to the chicken-tumor extract, inactivate the virus and prevent the growth of a tumor. When large amounts (25 per cent) of calcium carbonate are added, the virus is adsorbed and fixed, but the addition of only 1 per cent usually does not inactivate the virus. Thus far it has not been possible to determine in all cases whether the inactivation of the tumor virus by the calcium compounds is due to a chemical change or to its adsorption by the particulate matter. In some cases, such as calcium carbonate, where large amounts inactivate the virus but small amounts fail to do so, one may assume that the virus is adsorbed. Whether the inactivation of tumor virus by any such means will ever be applicable to the treatment of human tumors remains for the future to determine. It is, however, an approach that should be considered.

TECHNIQUE OF OBTAINING FRESH BLOOD OF THE FOWL

In carrying on investigations of living tissues there is frequent need of freshly drawn blood in abundant quantity. In the rabbit or guinea-pig the technical procedure for doing this presents no difficulties. In the fowl it is not so easily done. Mrs. M. R. Lewis has perfected a simple method by which the entire operation may be performed in ten minutes by one person without assistance. Using the second and third ribs as landmarks, the blood is withdrawn from the heart with a hypodermic needle. The details of the technique have been published for the benefit of other workers.

VASCULAR PATTERNS OF TUMORS

In studying the vascular pattern of different kinds of tumors, Dr. W. H. Lewis has made the interesting observation that each type of tumor has its own characteristic pattern, to the extent that one can even diagnose the kind of tumor in this manner. This is due to the fact that the vascular system is very plastic and responsive to its environment. That this is true in the embryo has been repeatedly pointed out in these reports. That it is also true in the adult is demonstrated by these experimental studies of Dr. Lewis. When a tumor particle is implanted in the subcutaneous tissue, it attracts into itself as it grows endothelial cells which multiply as the tumor increases in size and form vascular trees, just as they do normally in the tissues of the embryo. Different types of tumors, though starting in the midst of the same

vascular pattern, eventually develop each its own characteristic vascular network. Dr. Lewis points out that the blood-vessels do not determine the growth of the tumor; but the tumor determines the growth and pattern of the vessels. Purely epithelial tumors, for example the adenocarcinomata, develop a large sinusoidal circulation not unlike that of the embryonic liver, which is composed, essentially, of strands of epithelial cells. The five types of transplanted rat tumors studied by Dr. Lewis included fibrosarcoma, spindle-cell sarcoma, round-cell sarcoma, adenofibroma, and adenocarcinoma. The animals were injected with india ink, fixed and then thick slabs of the tumor cut and cleared for study. Beautiful vascular injections can be obtained in this way.

TISSUE CULTURES OF KIDNEY TISSUE

Dr. M. Nishibe, a guest in this laboratory from the Government Institute for Infectious Diseases, Tokyo, succeeded in cultivating kidney tissues of the adult toad in peritoneal fluid and lymph without any additional nutrient substance. As this may be done at room temperature, it constitutes a very simple method of studying living tissues. Dr. Nishibe has published an account of his observations, including a description of the character of the outgrowth and migration of the various cells and the finer cytology of the endothelial and mesothelial cells. The outgrowth of endothelial cells in such cultures is of particular interest. They were identified from other cells by their actual continuity with the endothelial cells lining the sinusoids between the kidney tubules. The epithelial cells, although they were living and showed active ciliary movement, gave no evidence of growth.

STUDIES IN EXPERIMENTAL EMBRYOLOGY

EXPERIMENTALLY PRODUCED MONSTERS

In the report for last year attention was called to the experiments of Dr. C. F. DeGaris on paramecium. He found that by temporarily exposing this unicellular organism to certain injurious fluids, or otherwise modifying their environment during the process of cell division, the process could be arrested in an uncompleted state, and if returned to a favorable medium the conjoined halves did not complete the division but continued to grow as components of a double monster. Such monsters could be kept alive 15 to 20 days, during which time some of them gave rise to normal or abnormal detached segments. The detached forms, if abnormal, either failed to divide and soon perished or, as was usually the case, became regulated through a series of divisions into normal forms. The detached forms, if normal, gave rise to normal progeny, no matter how grossly distorted their monstrous parent may have been.

Following the genetic studies of Professor Jennings, Dr. DeGaris has continued these experiments with the view to learning if monster formation, induced in pure lines of paramecium, produces changes in characters which are definitely known beforehand, such as fission rate and mean cell length. In order to provide a sufficient number of suitable specimens for such a statistical study, the following procedure was adopted. A cell just beginning division is transferred to a hanging drop of hay infusion and suspended

in a sealed chamber over a solution of potassium cyanide where it can be kept under observation. By experience one learns the right amount of intoxication necessary, at which time the hanging drop is removed from the cyanide chamber and sealed over a similar chamber of water, whereon the cell promptly recovers, though it usually does not resume division but remains a double monster. If division is resumed it may require a second or third exposure to the cyanide fumes. The amount of exposure depends partly on the cell and partly on the strength (age) of the cyanide solution. Starting with 28 specimens of paramecium, Dr. DeGaris followed them in pure line cultures for 85 days, determining their respective rates of cleavage (number of generations) and their mean cell length, the different lines varying sufficiently in these respects for easy recognition. Monsters then were produced for each line, after which each line was continued from the first free daughter-cell of the respective monster and cultured a further period of 85 days, and again the rate of cleavage and mean cell length being recorded. Tabulation of the figures before and after monster formation clearly proves that the experience of monster formation produced no significant change in any of the lines in the two basic characters, fission rate and mean size. Furthermore, since most monsters gave off more than one free cell, it was possible to collect data as to fission rate and cell length in successive progeny of the same monster. Five such specimens and their successive progeny were followed for a period of 85 days and, in spite of the increasing distortion and profound disturbance of cell organization, the later progeny retain their characteristic fission rate and mean cell length, unaffected by the experience of monster formation.

EFFECT OF ANTERIOR AND POSTERIOR SELECTION ON FISSION RATE

We have just seen that fission rate and mean cell length are features that remain fairly constant for any given pure line of paramecium and remain characteristic, even in the event of induced monster formation. Dr. DeGaris has extended his experiments to determine the possibility of demonstrating heritable diversities of fission rate by culturing, on the one hand, cells of anterior origin and, on the other, cells of posterior origin. This was suggested by Professor Jennings' success with *Diffugia*, where it was shown that by continued selection for certain diversities in character one could obtain from a single cell many stocks that were hereditarily different—an evolution based on continued minor heritable variations rather than cataclysmic mutations.

Selecting five dividing organisms, Dr. DeGaris isolated in each case the halves as anterior and posterior stock of the respective five lines. Again selection was further made from this stock for anterior and posterior origin of the subsequent branches, the rates of fission being duly recorded. He found in "line 1" and in "line 2" that posterior selections, as compared with anterior, showed a lower fission rate. On the contrary, in "line 3" the posterior selections showed a relatively high rate of fission. In "line 4" the anterior selections had a higher rate, as in "lines 1 and 2." In "line 5" the rates of fission were practically identical in the anterior and posterior selections. From these results it is evident that heritable diversities of

fission rate can be brought out in the progeny of two daughter-cells by selection of anterior and posterior cells, although sometimes it is the anterior stocks that give a higher mean of fission and sometimes it is posterior. It is to be noted, however, that in one line there was no appreciable difference in the fission rate of the anterior as compared with the posterior selections. The conclusion is therefore reached that it is not the fission rate itself that is inheritable as a fixed character, but the direction of change, and so if the direction of increment is associated with an anterior stock, it remains so in progeny. The experiments of Dr. DeGaris did not go far enough to answer the question as to whether the fission rate change was acquired all at one time in large degree or gradually by small degrees. His records show that the initial difference in rate is almost as great as the final mean change, and there is no evidence of a gradually widening difference in rate between anterior and posterior lines; but to be conclusive it will be necessary to culture a more extensive series of successive selections and also to note the time differences of fission in hours and minutes, which was not attempted in his study. His specimens were cultured on hollow-ground slides, with an alternating diet in five-day periods of hay infusion, hay infusion plus malted milk, and hay infusion plus beef extract. Since food has a profound effect on fission rate, this factor was carefully controlled.

DIFFERENTIATION OF THE FORELIMB IN AMPHIBIA

In the Year Book for 1924 I described the studies of Dr. F. H. Swett on transplantation of limbs in amphibian larvæ and the phenomena of regeneration, reduplication and orientation. The problem became complicated through the fact that the different axes of the limb primordium became determined at different times relative to each other and to the stage of development of the larva. This required a further series of experiments. While these were in progress Dr. Swett accepted an attractive position with Professor Cunningham in the Anatomical Department of Vanderbilt University at Nashville. In that new and well-equipped laboratory he has had facilities for the prosecution of his experimental studies, and during the past year his completed paper on the differentiation of the limb rudiment has appeared.

DEVELOPMENT OF THE MENINGES

After familiarizing himself with the normal process of histogenesis of the covering membranes of the central nervous system in amphibian larvæ, Dr. L. B. Flexner has made a study of these membranes where pieces of spinal cord and brain are transplanted. His objectives were to determine the influences of neural crest cells and the presence of cerebrospinal fluid on the formation of the meninges. This work has been completed and will appear in final form in the next number (vol. XX) of the Contributions to Embryology.

THE ORGANS AND MECHANISM OF REPRODUCTION

GESTATION IN *MACACUS RHEBUS*

During the past year Dr. C. G. Hartman has been able to obtain exact observations on the length of gestation in the *Macacus rhesus*. The chief

reason why reliable information on the gestation period in apes and monkeys was heretofore lacking is the fact that it has always been customary in zoological gardens to keep male and female monkeys caged together, where they repeatedly mate at all times with no definite "heat" periods. Under the arrangements of the Carnegie colony matings are possible only at recorded periods, which are determined with reference to the menstrual cycle and the vaginal secretions. A 12½-pound female specimen, 7 or more years old, which had previously borne young and which from 2 years' observations was known to have normal 26-day menstrual periods, was mated successfully and 6 lunar months later gave birth to a normally developed *rhesus* baby, which is now (June) 8 months old, is vigorous and is growing well. The fertile mating took place between the ninth and twelfth day after the beginning of the last preceding menstruation, and was just before the disappearance of the leucocytes from the vaginal secretion.

The character of the vaginal content was followed by Dr. Hartman throughout most of the gestation period. He found that a slight admixture of red cells was present from the fourteenth to the thirty-seventh day, resembling the "placental sign" that occurs in the rat. This phenomenon has been subsequently observed in other pregnant monkeys and apparently it is going to serve as a valuable early diagnostic sign. The cessation of the "placental" bleeding is followed by a prolonged vaginal leucocytosis. Among other phenomena accompanying pregnancy, serial data were obtained on the characteristics of the uterus and fetus as determined by abdominal palpation, the placental "bruit," and the color changes in the "sex skin."

PARTURITION IN *MACACUS RHEBUS*

Another "first" is to be credited to Dr. C. G. Hartman. He has succeeded in observing and recording in detail the process of parturition in a *rhesus* monkey, which apparently is the first time this phenomenon has been adequately studied in any primate other than man. This information is of course important to those engaged in the study of the mechanism of reproduction, but an instinctive act of such high complexity in a primiparous mother without previous experience or other guidance is also of importance to the student of animal behavior.

Knowing when parturition would likely occur, the animal concerned was observed day and night for 11 days prior to delivery for any premonitory symptoms. The only positive signs were a growing restlessness, increased quickening from fetal movements, evidence of "pains," increased mucous discharge from the vagina, greater frequency in micturition, and the presence of motile leucocytes in the vaginal secretions. With no other signs that labor was imminent, parturition began and was completed in a little less than an hour, every phase being observed in a good light by Dr. Hartman and a group of assistant observers. The outstanding features were the half-sitting posture, the unquestionable involuntary and reflex nature of the muscular contractions, and the eating of the placenta. The subsequent behavior of the mother and baby were carefully followed. It is interesting to note that the baby finds the nipple by trial and error with its own efforts, the mother assisting only by automatically holding the baby to her bosom.

From this case and others Dr. Hartman has made further observations on gestation. In 3 cases the duration was 159, 168 and 174 days respectively, the latter being a primipara. Conception apparently takes place before the leucocyte content of the vagina reaches zero, which is about 10 days after the beginning of the preceding menstrual flow. The female *macaque* does not arrive at sexual maturity before the fourth year and then there is a year or more of irregularity in menstruation and ovulation before maturity is established. In all 4 cases thus far seen by him, Dr. Hartman finds red cells in the vagina, the "placental sign," from the fifteenth to the thirty-seventh day of gestation. His observations on the change in the character of the uterus, as detected by abdominal palpation, toward the end of the tenth week are of diagnostic importance, as are also his data on increase in size of the abdomen and mammary glands and the phenomenon of version, the latter occurring between the one hundred and thirtieth and one hundred and thirty-seventh day of the 174 days' gestation period.

THE CORPUS LUTEUM FACTOR IN MENSTRUATION

That menstruation under certain circumstances may occur with an interval endometrium was found to be true by Dr. C. G. Hartman. A surgical rupture of a large ovarian follicle of a *rhesus* monkey, which had been associated with a marked edema of the sex skin, was followed seven days later by menstruation. Thereupon the uterus was removed and the endometrium was found to be in the interval condition with no glandular hypertrophy. The uterine epithelium was sloughed off in places, as is usual in menstruation, and there was blood in the uterine cavity. This experience proves that an enlarged ovarian follicle may occur with edema of the sex skin without, however, any approach to the premenstrual condition of the endometrium and uterine glands. Evidently, for the latter purpose the ovary must contain a corpus luteum, which was not the case in Dr. Hartman's interesting experiment.

DIFFERENTIAL COUNT OF THE VAGINAL LEUCOCYTES IN THE RAT

In order to determine precisely the relative predominance of the different types of leucocytes present in the vaginal secretions during the metœstrous period, Mr. C. G. Post jr. examined lavages and smears of five apparently normal rats for a period of 30 days. By using dilute stains he could accurately distinguish three prevalent types; monocytes, lymphocytes and polymorphonuclears. The series of differential counts of these cells gave the same results in lavages as in the smears, proving that the two methods are equally trustworthy for that purpose. Polymorphonuclears constitute 95 per cent or more of the leucocytes present; monocytes vary from zero to 4 per cent, and lymphocytes range from zero to 2 per cent.

OVARIAN STUDIES

Utilizing his rich collection of opossum material, Dr. C. G. Hartman has made a survey of the ovaries for certain anomalous characters. He found that out of 132 ovaries, each taken from a different animal, 27 possessed a definite outgrowth of some kind other than stigmata or lutein plugs. Eight of these outgrowths consisted of normal ovarian tissue, more or less

constricted from the surface of the ovary and presenting every gradation from broadly sessile bodies to pedunculated ones connected with the ovary only by a narrow stalk. These structures appear to be identical with the accessory ovaries described by Beigel in the human ovary. Their significance is not fully understood. Apparently they arise at an early age and persist throughout life, subject only to those changes incident to the growth and retrogression of follicles. Whether they are to be interpreted as stages leading toward complete separation can only be established by further study. The other outgrowths from the surface of the ovary included accessory fimbriæ, outgrowths from the albuginea and basal processes with embryonic germinal epithelium.

In four of the animals studied by Dr. Hartman the ovaries were found to contain pathological corpora lutea associated with death of the embryos. The corpora lutea were either hemorrhagic, defective, or prematurely involuted. These cases are of interest in that they have a bearing on the problem of the rôle of the corpus luteum in pregnancy. Dr. Hartman concludes that the death of the embryos was secondary to the involution of the corpora, but points out that since the opossum does not have a placenta or decidua, the termination of pregnancy must be due to a disturbance in the normal turgid condition of the uterus.

A third anomalous condition of the ovary was discovered by Dr. Hartman, namely, the presence of what appears to be adrenal tissue. Accessory adrenal glands had previously been reported in the broad ligament but never in the ovary itself. This may be explained by the similarity of corpus luteum and adrenal tissues. In this case Dr. Hartman's thorough familiarity with the normal ovarian histology in the opossum made it possible for him to detect this foreign tissue and to put this unique case on record.

It will be recalled that in the collecting trips to Nicaragua the organs of reproduction were obtained from a large number of mature female American monkeys, *Alouatta palliata* and *Ateles geoffroyi*. A careful histological study of the ovaries from these specimens has been made by Dr. F. F. Snyder in the School of Medicine of the University of Rochester. From his observations it would appear that it is not the activity of the lutein cells that is responsible for the inhibition of ovulation in primates. He finds an ovary in which a follicle had recently ruptured, although the ovary was packed with large follicular cells, of the two types characterizing granulosa cells and theca interna cells. A preliminary account of this has appeared and it is hoped that a complete report on the material may be completed in the near future. Dr. Snyder returns to the Johns Hopkins Hospital this coming autumn.

THE TUBO-UTERINE JUNCTION AND ITS LYMPHATICS

Mention has been made in previous reports of the observations of Dr. F. C. Lee on the periodical patency and closure of the tubo-uterine junction; that it is sometimes easy to force india ink from the uterus into the tube, while at other times it can not be done even under high pressure. For the purpose of seeking a possible structural explanation for this phenomenon, Dr. Lee has made a careful gross and microscopic examination of this

region in a variety of common animals, namely, rabbit, pig, mouse, rat, guinea-pig, cat, dog and lioness. The most constant factor was found to be the presence of a well-developed circular layer of plain muscle fibers constituting an effective sphincter at the junction of tube and uterus. In addition, the uterine mucosa in the immediate neighborhood of the tubal opening is thrown up in numerous polyp-like projections which serve as a valve blocking the passage of materials from the uterus to the tube. The character of these peculiar mucous folds, however, is not constant. They are largest and most numerous in the pig and rabbit, where they are plainly visible to the naked eye, whereas in the rat and dog they exist only as small folds. The effectiveness of this tubo-uterine valvular mechanism is so great that one can rupture the uterine wall before any of the injection mass escapes into the tube. This intricate mechanism may be expected to prove of clinical significance and perhaps may afford an explanation for certain hitherto poorly understood abnormal states of the tubo-uterine tract.

From the studies on the lymphatics of the oviduct of the sow, published by Dr. D. H. Andersen in the last volume of the Contributions to Embryology (vol. XIX), we know that the polyp-like projections at the tubo-uterine junction contain numerous large lymphatic sinuses, which were also recognized by Dr. Lee. It is evident that the degree of distention of these lymph spaces will affect the size of the projections and the consequent effectiveness of the valve. Dr. Andersen's description of the pattern of the lymph-vessels within the tubal wall is the first adequate treatment of this subject, and in addition to its contribution to our knowledge of the distribution of lymphatics it will be one of the steps by which we may hope to approach the problem of tubal physiology.

An interesting feature demonstrated by her beautiful injections is the adaptation of the lymphatics to the functional requirements of the different parts of the tube, as expressed in pattern. Thus Dr. Andersen shows that the subserous net is quite different in character from the submucous, and that the subserous is not everywhere the same but is especially developed at the isthmus and tubo-uterine junction. Likewise the submucous plexus of the ampulla is different from that of the isthmus. In the ampulla in the center of the mucosal folds it has conspicuous sinus-like spaces, the purpose of which is still only a matter of conjecture. It is certain that so large a drainage system is of definite functional significance. The final drainage of the two lymph capillary plexuses, the subserous and mucosal, is through common valved collecting vessels into the large lymphatic vessels of the mesosalpinx.

PLACENTATION

IMPLANTATION OF THE PIG OVUM

The ungulate placenta, compared with that of most other mammals, is a simple one in that the fetal membranes remain intact and distinct from the uterine tissues, the attachment being of contact only. In order to determine the structural factors of fetal nutrition under these conditions, Dr. C. H. Heuser has studied a large series of pregnant and non-gravid uteruses of the sow. He has found, in the first place, that the uterine glands play a greater part in the nourishment of the embryo in this type

of placenta than in animals where there is a more intimate blending of the maternal and fetal tissues and freer interchange of blood-carried materials. The evidence for this is that in the latter animals the uterine glands remain unchanged or degenerate as pregnancy advances, whereas in the pig the glands show a marked growth, both in the number of terminal branches and in volume. Dr. Heuser was able to demonstrate this increase in glandular epithelium by an improved method of isolation and dissection of individual glands, by which method he at the same time has provided us with a better acquaintance with the detailed form of the uterine glands in the ungulate.

The glands pouring out the uterine secretion terminate in cup-like depressions on the surface of the mucosa, the size of the cup corresponding to the size of the gland. There is usually one gland to each cup, but there may be as many as three. Fitted into these cups are the areolæ, or crater-like elevations of chorion which are provided with a characteristic radiating net of capillaries and epithelial folds and villi, appropriate for the absorption of the glandular secretion. These areolæ are specialized areas of the chorion and are concerned with the uterine glands. The remaining surface of the chorion is found by Dr. Heuser to have a different type of capillary net and it evidently performs a different function. It is here that we must look for any interchange of materials between the fetal and maternal blood—for example, respiration. The surface area of this part of the chorion is greatly increased through being thrown up in minute tufted folds and villi, which fit nicely in corresponding fossæ of the uterine mucosa, and the area of contact is still further increased by the major folds or rugæ of the uterine mucosa and chorion. The fetal and uterine surfaces are thus held in secure apposition by this intricate system of interlocking corrugations, an arrangement that both facilitates the nutritional mechanism and at the same time anchors the fetal sac.

As differing from the ordinary fossa between the chorionic villi, Dr. Heuser has discovered certain pocket-like depressions of the chorionic epithelium which normally occur after the embryo reaches 45 mm. in length. These specialized pits enlarge and, maintaining a duct-like communication with the surface, become sunken vesicles covered with a characteristic capillary plexus. From the appearance of their lining epithelium, Dr. Heuser regards them as having a temporary period of secretory activity. As they advance in age and grow larger the duct becomes smaller and in some cases entirely closes, converting them into cysts with degenerate epithelium. These structures, then, are to be regarded as specialized areas of chorionic epithelium, and we must therefore reckon with at least three discrete functional areas in the chorion of the pig, namely: (1) the areolæ; (2) the secretory vesicles of Heuser; and (3) the general villous surface of the chorion. The ground is now prepared for a physiological or microchemical exploration of these different areas.

PLACENTATION OF PRIMATES

Our present information on the mechanism by which the nutrition, respiration, and excretion of the fetus is accomplished is extremely meager. For the most part it is limited to the deductions that may be made from a few

experiments showing the permeability of the placenta to various solutions of salts, acids, and certain dyes. Because of the histological complexity of the human placenta, it has been difficult to interpret the significance of its structural elements. As we grow acquainted with various types of placentæ, however, certain common fundamental features begin to come to the surface. Indeed, much may be expected from studies of the comparative anatomy of the placenta toward the solution of this functional problem of fetal and maternal interchange. The observations of Dr. G. B. Wislocki are leading toward such an understanding of this enigmatical organ. During the past year he has made a comparative study of the primate placenta and has found that in the manner and degree of proliferation of the trophoblast the platyrrhine monkeys exhibit the most primitive and profuse type. The catarrhines are somewhat less so, whereas in the anthropoid apes the trophoblast is no longer a syncytial network but is reduced to a thin covering of the villi. Another feature of the placenta that distinguishes the anthropoids and man from the monkeys is its interstitial implantation and consequent capsularis. Dr. Wislocki points out that the gibbon in this respect, as well as in the structure of the villi, belongs among the anthropoids.

PLACENTATION OF HYRAX

As a contribution toward Dr. Wislocki's program of study of the comparative anatomy of the placenta, he obtained through the generous cooperation of the United States National Museum a pregnant uterus of *Hyrax* containing an embryo of 21-mm. crown-rump length. This proves to be an extremely interesting primitive type of implantation with little or no traces of ungulate features, and much more closely resembling the burrowing deciduate type found in rodents, insectivores, and the primates. There is a diffuse proliferation of trophoblast over the whole surface of the blastocyst, with invasion of the endometrium and production of a labyrinth of trophoblastic strands in the meshes of which are found sinuses filled with maternal blood. On the fetal side there is a narrow zone of vascularized mesoblast corresponding to the chorionic membrane, from which simple villi project a short distance in the trophoblast. The nutrient exchange must occur between the maternal lacunæ enclosed by the labyrinthine trophoblast and the fetal capillaries of the narrow villi-covered zone of mesoblast. This growth of mesoderm and trophoblast and invasion of the endometrium on all sides of the blastocyst apparently obliterates the greater part of the uterine cavity. The growth, however, is much greater in the equatorial zone and at the poles is scant. It is pointed out by Dr. Wislocki that, contrary to our former belief, the burrowing type of placenta, such as *Hyrax* represents, is the archaic type and close to the phylogenetic stem; whereas the diffuse type, such as is found in ungulates, is a secondarily derived form and occurs in highly specialized and divergent groups. Thus, though *Hyrax*, as judged from its morphology and the findings of paleontology, is placed near the ungulate stems in close affinity to the Proboscidae, one finds in respect to implantation that he bears no resemblance to the existing representatives of those families, and should rather be regarded as of proto-ungulate stock.

PLACENTATION OF THE THREE-TOED SLOTH

An important investigation of the reproductive tract of the sloth has been made by Dr. G. B. Wislocki. As material for such a study is quite rare, Dr. Wislocki was fortunate in obtaining the generous cooperation of Dr. James Zetek, Custodian of Barro Colorado Island Laboratory of the Panama Canal Zone, and during the course of two years 41 female specimens were obtained, 28 of which proved to be pregnant. Owing to the favorable location of the laboratory, valuable observations were made with regard to their reproductive period. The breeding season was found to extend over the months of January, February and March and gestation occupies from four to six months, a relatively long period and with consequent relatively mature offspring.

Dr. Wislocki made a careful study of the entire reproductive tract, both in the gravid and non-gravid state, but the placenta and fetal membranes were the particular structures toward which his attention was directed. The placenta is deciduate and composed of lobules in which a labyrinth is formed of maternal and fetal vessels. The modified endothelium of the maternal vessels is enclosed by a delicate reticulum of connective tissue fibers, which in turn are enclosed by lamellæ of trophoblastic syncytium, at first broad and conspicuous, later thin or even totally disappearing. Beneath the trophoblast there appear as development progresses, in the interlamellar fetal stroma, large epithelioid cells which rest as a layer against the thin sheet of trophoblast. Dr. Wislocki, on the basis of these characteristics, regards the sloth placenta as representing the syndesmochorial type of Grosser's classification, unless the reticular network of the maternal vessels is disregarded, which would throw it in the endotheliochorial group. It is rather a transition between the two.

In the character of its labyrinth this type of placenta closely resembles that of the dog and cat. There is, however, no hypertrophy of the uterine glands as occurs in the latter and none of the peculiar hæmatomata that are supposed to supply embryotrophic nourishment in the dog and cat. Dr. Wislocki points out that this function may be supplied by the widespread resorption of placental lobules that characterizes the sloth as pregnancy advances. It is important to note that in the character of its reproductive tract the sloth resembles the ant-eater and armadillo and that these three American edentates show only a remote relationship, if any, to the Old World edentates, and it is evident that they must be classed as an entirely separate order, *e.g.* *Xenarthra*, as proposed by Weber.

This material provided Dr. Wislocki with the opportunity of making observations on the fetus itself in a close series of stages, ranging from 27 mm. to 171 mm. spine length. The development of the hair and epitrichium are features of special interest.

PLACENTA OF THE TWO-TOED ANT-EATER

Through the courtesy of Mr. Gerrit S. Miller jr., of the United States National Museum, Mr. G. B. Wislocki has had the opportunity of studying the pregnant uterus of a two-toed ant-eater which, like the sloth, forms one of the groups of American edentates. This material is quite rare and

one can judge of the character of implantation only from isolated specimens of this kind. For adequate analysis of the edentate placenta it has become evident that there is needed a complete series of developmental stages for each family—the sloth, the armadillo, and the ant-eater—just as is true for all comparative studies of the placenta. Such a series does not yet exist for the ant-eater, but from the specimen described by Dr. Wislocki and others reported in the literature, it is evident that the female reproductive tract of the ant-eater resembles more that of the sloth than the armadillo, although all three show similarities. The gravid uterus of the sloth and the ant-eater are almost identical in the form of their glandular zone beneath the placenta as well as the paraplacental regions. In respect to the placental labyrinth, however, the ant-eater resembles more nearly that of the armadillo, being villous in type, whereas that of the sloth is lamellar. All of the American edentates have a burrowing type of placenta which links them to the deciduate groups and distinguishes them from those mammals with a diffuse placenta, such as the ungulates. It is to be added that the two-toed ant-eater, in common with the other American edentates, shows no similarity in its placentation to the Old World edentates. In the latter the placenta is deciduate and is said to resemble that of the ungulates.

In studying the fetus in this case, measuring 83 mm. long from snout to base of tail, Dr. Wislocki finds that it does not have a free epitrichial membrane, which structure forms such a conspicuous envelope in the sloth.

NERVOUS SYSTEM

STRUCTURAL AND FUNCTIONAL DEVELOPMENT OF THE CEREBRAL CORTEX

The histological studies of Dr. O. R. Langworthy of the cortical areas in the cat and opossum of various ages have been completed and have appeared in their final form in volume XIX of the Contributions to Embryology. In these studies Dr. Langworthy has described certain areas that can be delimited by their response to electrical stimulation and he has determined the correlation existing between their functional capacity and their structural characteristics.

For the study of the development of the brain the opossum presents certain advantages, for the young are born at the end of the twelfth day of gestation, at which time they are only about 11 mm. in length. Their forelegs are well developed but their hindlegs are still bud-like, and most parts of the body are in a corresponding embryonic stage of development. The brain was exposed and the cortex explored with the unipolar electrode in 13 pouch young, varying from 23 days to 89 days, and in 8 adult animals. In this way Dr. Langworthy was able to identify an area for the foreleg musculature lying posterior to the orbital sulcus near the midline, extending across the sulcus and a short distance anterior to it. A center which yields contraction of the facial-masticatory muscles was located anterior to the sulcus and lateral to the foreleg area just mentioned. No hindleg center was found. The foreleg center reacted to stimuli in 23-day-old pouch young before the orbital sulcus had formed. The facial-masticatory center could not be demonstrated until the young were about 76 days old. Histologically, the foreleg center is the first to be differentiated, and it is in this

region that the orbital sulcus first develops. Spreading from here, the motor-cortex type differentiates anteriorly and laterally into the facial-masticatory region, and in the adult opossum the two centers are more or less blended histologically. A non-granular frontal area can be distinguished, situated anterior to the electrically responsive cortex. These regions constitute a rather small portion of the total cortex, but they constitute all that have thus far been subject to satisfactory functional and histological correlation in these primitive mammals. The smallness of the area is, of course, chiefly accounted for by the fact that functional control is only possible in motor areas.

Extending his studies from the opossum to the cat, Dr. Lanworthy has completed his series of observations on the histogenesis of the cortical motor areas in this relatively higher mammal. In a large series of adult cats he made a careful electrical exploration of the motor cortex and demarcated six areas, three anterior and three posterior to the cruciate sulcus, based on the muscular response following their stimulation. These same areas were also tested in kittens covering the first 50 days of postnatal life. After being tested, these areas were studied histologically to determine to what extent the different areas, as functionally mapped out, differed in structure. The first area to develop is that presiding over foreleg movements, which at birth can be definitely demarcated and histologically is distinctly more mature than the other centers. From then on, the maturation of the motor areas is progressive and this was followed, step by step, in respect to the variations in the development of the different layers and the arrangement, size, and structure of the pyramidal cells. The hindleg area can not be demarcated until the kittens reach the sixteenth day and the facial-masticatory area does not respond to stimulation until the twenty-first day. It is interesting to note that the wall of the sulcus adjoining this area, as compared with the others, possesses the largest pyramidal cells and may perhaps be regarded as the newest phylogenetically, whereas the smallest pyramidal cells are found in the forelimb area, which in contrast seems to be the oldest phylogenetically. The presence of the cruciate sulcus complicates the matter of electrical exploration. That part of the cortex buried in it can not be satisfactorily reached with the electrode. From the histological appearance it is probable that important centers are situated in the wall of the sulcus. In general it is demonstrated by Dr. Langworthy's observations that the areas, as mapped out by the electrode, are structurally different areas, which in turn indicates that stigmatic exploration is a reliable test of functional differentiation.

As part of this study, attention was directed to the myelinization of the pyramidal fibers, the large cortico-spinal motor tract. No myelin was visible for the first nine or ten days after birth and the myelinization was not complete until the kittens were approximately 50 days old. From this it is evident that the response in the foreleg muscles, which is present at birth, is not dependent on the presence of myelin in the pyramidal tract. The hindleg and facial centers, however, become responsive at about the time myelinization begins.

CORRELATION BETWEEN REFLEX ACTIVITY AND MYELINIZATION

In connection with his histological studies of the developing nervous system in fetal and young kittens, Dr. O. R. Langworthy has directed his attention to the temporal relation existing between the behavior of young animals and the myelination of their simpler reflex arcs. This is relatively easy in young animals, where the behavior is simple and where only few fibers are medullated. He was able to demonstrate that bilateral movements of the extremities begin to coordinate when the ventral commissure of the cord receives its myelin. The animals turn the body when myelinated vestibular fibers reach the spinal cord. The hindleg movements become better coordinated when myelination becomes marked in the lumbar cord. In observing the general course of myelination it was found that the ventral spinal roots become medullated before the dorsal. Myelination occurs first in the cervical portion of the cord and progresses caudally. The fibers of the dorsal columns of the cord myelinate slowly, the cuneatus fibers earlier than those of the gracilis. In the brain-stem it is the nerve of equilibration (vestibular) and its connections that are first to medullate.

CONTROL OF POSTURE

When one reviews the present status of the problem of postural control, as has recently been so well done by Dr. O. R. Langworthy, it becomes evident that many conflicting observations remain to be harmonized and that the field is still rich in opportunity for the investigator. There exist certain technical difficulties in functional studies of this mechanism, such as arise from the fact that pathways producing and those restraining the postural reflex may be either stimulated or interfered with by the same procedure. Also the reflex arcs involved are extensive and there are many points the stimulation, or interruption, of which results in the same equivocal effect. Dr. Langworthy points out the probability that nearly all portions of the central nervous system have a part in the control of the postural reflex and, with the progressive development of the brain, this control is progressively assumed by higher levels.

In outlining the principal pathways through which postural control is maintained, Dr. Langworthy includes the proprioceptive fibers from the muscles of the extremities as carriers of the predominating afferent stimuli. These stimuli are transmitted to the vermis of the cerebellum by the dorsal and ventral spino-cerebellar tracts and by fibers from the nuclei of the posterior columns. Further proprioceptive fibers pass rostralward through the medial lemniscus to the thalamus and finally to the cerebral cortex, giving off collaterals to various structures in the brain-stem, thereby producing reflex connections of much complexity. The cerebellum is ranked by Dr. Langworthy as the chief center of control. From its vermis excitatory or inhibitory impulses may leave by at least three prominent systems, namely, reticulo-spinal, vestibulo-spinal, and rubro-spinal. To these should be added, for higher forms, tracts from the corpus striatum and cerebral motor centers, which exert their influence either directly or through the cerebellum. The various efferent pathways from the brain lead to the somatic motor cells of the ventral horn and the nuclei of certain cranial

nerves, which, by virtue of their fibers to the striated muscles, finally determine the tone and contraction of the respective muscles. In studying postural reflexes one must therefore take into consideration the relative function of these various pathways, and not only as concerns particular animals but also their degree of ontogenetic development. In his review of this general problem Dr. Langworthy makes frequent recourse to the studies of Professor Weed on decerebrate rigidity and the mechanism of postural control and the influence of the mesencephalic and cerebral centers on these reflexes. Also Dr. Weed's developmental studies of the maturation of the postural reflex in young animals are reviewed and the study made with Dr. Langworthy on development of progression and posture in young opossums. The comparative and embryological studies of Langworthy, and of Bagley and Langworthy, and the observations of Dr. King on the cerebral influence upon this reflex, all of which have been referred to in these reports, form important sources of the data upon which his conclusions are based.

AREA FRONTALIS AND ITS CONTROL OF THE POSTURAL REFLEX

An account has previously been given of Dr. King's electrical exploration of the frontal region of the adult cat brain, the plotting of the excitatory areas surrounding the cruciate sulcus, and the demonstration of an adjoining frontal gyrus which does not respond to electrical stimulation but removal of which leads to more or less marked permanent extensive rigidity in the hindleg of the opposite side, that is to say, a cortical area of postural control. During the past year this fruitful study has been continued and extended in scope by Dr. O. R. Langworthy. In the first place, he repeated the electrical stimulation of the cortex and verified the contours of the responsive areas, found only in the limited region of the convolutions in front and back of the cruciate sulcus. Histological preparations were made of these motor areas and it was found that they each possess more or less definite structural characteristics which is expressed by the form, size, and distribution of the nerve cells. Experiments were then extended to the non-responsive area frontalis, including its removal on one or both sides. The immediate effect was observed and also some of the animals were kept for study over a duration of three months. The latter were particularly instructive, as they demonstrate that the extensor hyper-tonus that results on the opposite side is not a transient irritative phenomenon due to cortical injury, but is a permanent state. The area frontalis was studied histologically and it was found to blend posteriorly and laterally with the electrically-responsive motor area. Anteriorly it ends abruptly and from that point forward the cortex is thinner and embryonic in appearance. Mesially the frontal area is continued upon the mesial surface of the hemisphere.

A matter of particular interest is the course of the efferent fibers from the area frontalis which must transmit the impulses that normally control postural tone. Dr. Langworthy examined his material for evidences of degenerated paths both in Weigert and in Marchi preparations and sought to trace them. In the former preparations he could trace injured fibers

through the mesial portion of the cerebral peduncle as far caudally as the pons. The Marchi material was not so conclusive. Additional information was secured by experiment. By cutting the cortico-spinal (pyramidal) tracts on both sides at a level just above the first cervical vertebra, he found there was no abnormal extensor rigidity in the leg muscles, proving that the rigidity that follows the removal of the frontal area is not due to a release of the control of the cortico-spinal fibers on the cells of the primary reflex arc. When, however, the cortico-pontine tracts are severed, as can be done by exposing the pons through the mouth and cutting the pontine fibers in the midbrain, the animals behave in the same way as those in which the frontal area is removed on both sides. Thus Dr. Langworthy provides us with good evidence that the control of the postural reflex by the area frontalis is mediated through the cerebellum.

RELATION OF MOTOR CORTEX TO CONVULSIVE PHENOMENA

An entirely different approach to the study of the function of the cerebral cortex has been made by Dr. W. S. Muncie and Dr. A. J. Schneider. They have shown that when the convulsant drug wormwood (absinthe) is given to cats there is produced a period of excitement preceding the onset of convulsions, at which time the motor cortex is more irritable to stimulation than normally. On the other hand, if the motor cortex is electrically stimulated during the actual convulsion, the violence of the convulsion is not increased. Instead, stimulation tends to inhibit the activity of the lower motor centers with disappearance of the clonic movements—a new demonstration of the inhibitory action of the cerebral motor cortex. In the period immediately following the convulsion the motor cortex is excitable, even to strong currents, and the return to normal response is a gradual one.

The particular inquiry with which these investigators were first concerned was the relation of chronic injuries of the central nervous system to convulsive seizures and for the purposes of experiment cats were used and the convulsive state was produced by varying doses of absinthe. They first determined the minimal dose required to produce a convulsion and the mean for 7 cats proved to be 2.08 c.c. oil of wormwood per kilogram of body weight. They then determined how the effect is altered when administered to animals in which the motor cortex had been previously (5 to 14 weeks) injured, and found that the necessary dosage is lowered in the proportion of 1 : 2. Furthermore, the character of the seizures was slightly altered, the onset and recovery were more abrupt. These were the results with minor injuries. When major injuries, with extensive removal of the motor cortex, were tested, it was found that the susceptibility to convulsions is lessened and the amount of wormwood necessary to start the seizures as compared with normal animals had to be increased in the proportion of 3 : 2. It is interesting to note that in these cases the convulsions were bilateral and generalized, even in animals with one entire hemisphere removed. A few experiments were made on cats in which the injuries were made in the spinal cord, transection of posterior columns and spino-cerebellar tracts. After they had recovered from their ataxia and had established a new mechanism of control, they proved to be less stable than normal

animals, succumbed more easily to the effects of the drug, and about half the dosage was necessary to produce convulsive attacks. These observations have a definite bearing on the problem of epilepsy in man and it is just such investigations that must lead us to an understanding of that serious disease.

SKELETAL MUSCLE TONUS

Important evidence on the disputed question as to the existence of dual innervation (somatic and sympathetic) in muscle tonus was obtained by Dr. F. D. Coman, who was able to demonstrate in the foreleg of the dog and cat three significant experiments; (a) stimulation of the sympathetic innervation of the foreleg does not cause any tonic reaction; (b) cutting the sympathetic innervation of the foreleg does not alter the normal development of tone, either before or after decerebration; (c) cutting the somatic innervation, on the contrary, is followed by complete abolition of tone. These studies were referred to in a previous report and at that time the conclusion seemed justified that there is no direct relation between the sympathetic nervous system and postural tonus in skeletal muscle. Still further evidence in support of this conclusion has been obtained by Dr. Coman during the past year. His new experiments show that in the lumbar region skeletal-muscle tonus is dependent upon an intact cerebrospinal proprioceptive reflex arc. Intradural unilateral section of the dorsal roots of the fourth to seventh lumbar and first and second sacral nerves, if carefully done without injury to the ganglia or spinal cord, is followed by complete loss of tonus in the limb involved, and postural contraction was abolished and did not return. When, however, the spinal cord was injured during section or avulsion of the roots, a slight spasticity occasionally develops in the limb as the anesthesia wore off, but this lasted never longer than 36 hours and appeared to be a transient irrational phenomenon. Such limbs subsequently became flaccid and remained so. Similar results were obtained when the spinal ganglia were injured, either by cutting or stretching. Even in the presence of these injuries no case was encountered that exhibited unequivocal and sustained hypertonia, which is contrary to the view held by those who assert that antidromic parasympathetic impulses cause hypertonia in limbs whose dorsal nerve roots are sectioned close to the cord.

MUSCLE INNERVATION

Continuing her studies on the innervation of skeletal muscles, Dr. Marion Hines, with Dr. S. S. Tower, has investigated the nerve connections of the muscle spindles of the forepaw of kittens. With the methylene-blue technique applied to experimental degenerations, these investigators have been able to make trebly sure as to the dorsal root ganglion being the location of the cell of origin for the equatorial ending of the spindle and that the fiber to the polar plaque comes from a somatic motor cell. They found no evidence of the sympathetic nervous system taking any part in the innervation of the spindle fibers and raise doubts as to the correctness of Cuajunco's interpretation of the intermingling sympathetic fibers.

The technical procedure adopted by Dr. Hines and Dr. Tower for determining the central connections of the nerve endings of the muscle

spindles involved sectioning the different nerve connections and, after waiting a few days for degeneration to ensue, injecting the whole animal with methylene blue. At the same time the skin and fascia were removed so as to expose the small muscles of the foot to the air, the injection being continued until the spindle terminations became visible. As soon as this occurred the fixative was run through the animal from one to two hours, whereupon the individual muscles were mounted in glycerine for study. In case of the interossei one could study the whole muscle in one mount. In this manner these investigators obtained brilliant preparations of the nerve endings, both normal and those in various stages of degeneration.

The muscle spindles were carefully studied in four muscles (Mm. interossei, pectoralis major, abductor digiti quinti, and lumbricales) and it was found that, although the details in the morphology of the sensory terminations vary in these different muscles, they nevertheless have two features in common, namely, the equatorial ending is medullated at its point of contact and the polar ending is non-medullated, although it originates from a medullated fiber. It was the question of origin of the fibers to these two kinds of endings that the experiments were devised to answer. It was first found that when the ventral somatic nerve roots to the forefoot are severed it is followed by degeneration of the polar endings on the spindle fibers, as well as the motor end plates of the ordinary muscle fibers. When the posterior nerve root ganglia are destroyed the equatorial endings in the spindles degenerate while the polar endings do not. When both the ventral and dorsal roots are severed all the nerve terminations in the spindles are destroyed. It was thus made clear that the polar nerve endings of the muscle spindles originate from cells lying in the somatic motor columns of the spinal cord and that the equatorial innervation has its cell body in the dorsal root ganglion. That the sympathetic nerves are not concerned was proved by the removal of the inferior cervical ganglion and the sympathetic chain in the neck. This procedure caused no degeneration in the spindles. Although the nerve to the polar ending may be devoid of a myelin sheath in the region of the spindle, and may resemble a sympathetic nerve, if traced back toward its source it will be found to be surrounded by a medullary sheath. They thus found that the absence of a myelin sheath is not an adequate criterion of a sympathetic origin for a nerve fiber and concluded that the sympathetic nervous system plays no part in the innervation of the muscle spindle.

Small muscles like the interossei present the advantage of displaying the muscle spindles *in situ*. Dr. Hines and Dr. Tower were thus able to demonstrate that the number of spindles in a given muscle is more or less constant, as is also the position in which they are found in that muscle, different muscles having their own characteristics in these respects. The amount of encapsulation of the spindle is variable from muscle to muscle, as well as within the same muscle. The spindles in the interosseous muscles, and especially the large one in the center, are more heavily encapsulated than the spindles in the pectoralis major. In considering the detailed form of the spindle it is interesting to note that the equatorial ending tends to be simpler in muscles having greater amplitude of movement and to be more complicated in muscles having finer adjustment of movement.

MEMBRANOUS ENVELOPES OF THE CENTRAL NERVOUS SYSTEM

A chapter on the cytology of the cerebrospinal pathway has been compiled by Dr. G. B. Wislocki for a reference book on Special Cytology, edited by Dr. E. V. Cowdry. Owing to his close association with a group of workers who have in large share contributed to the evidences upon which our present conception of the meninges as a functional system is based, Dr. Wislocki is particularly well equipped for the preparation of such a review. The workers I especially refer to are Weed, Essick, Woollard, Elman, Kubie, and Hansen-Pruss, and Wislocki himself. Accounts of their work have been given from time to time in these reports. In Dr. Wislocki's chapter the topics that are securely based on their observations are the following: (a) the development of the meninges; (b) nature of the sub-arachnoid spaces and their relation to the perivascular and perineuronal spaces; (c) mesothelial cells lining the arachnoidal trabeculæ and the problem of the origin of macrophages that appear under certain conditions in the cerebrospinal fluid; (d) origin and direction of flow of the cerebrospinal fluid; and (e) the major drainage of the cerebrospinal fluid through the arachnoid villi in the dural sinuses and the accessory drainage of cerebrospinal fluid into the lymphatic system along the spinal nerves.

MESENCEPHALIC ROOT OF TRIGEMINAL NERVE

From a morphological study of the cells that give origin to the mid-brain root of the trigeminal nerve, evidence has been obtained by Dr. A. J. Schneider that they are sensory in function and are analogous to the primary sensory neurones found in spinal and cranial ganglia. By preparing the brain-stem of six-weeks-old dogs with an improved silver impregnation method (Campbell), he secured serial sections through the mid-brain region showing nerve cells with their various types of processes, the medullated and non-medullated fibers being more or less differentially stained.

The characteristic of greatest interest was end bulbs terminating upon the surface of the large cells and especially in the cephalic and ventral portion of the cell group. These bulb-like structures stain intensely black with the silver. There may be but one or two bulbs terminating about a single cell, but sometimes they are so numerous that the outline of the cell is obscured. The fibers giving origin to these endings are of variable thickness, but their source could not be traced. The bulbs vary in size from slight varicosities of the fiber to masses one-fifth the size of the nerve cells and they are variously disposed with reference to the fiber and to the nerve cell, but within limits that mark them as a definitely characteristic structure, always stained intensely and homogeneously black.

The cells of origin of the mesencephalic root have the histological appearance of sensory cells. They vary in size and in number of processes. In general the larger cells are unipolar and lie in the more ventral portions of the group. Bipolar and multipolar forms are more common among the smaller cells and these are found in the dorsal portion but are also scattered among the large ventral cells. Occasionally, large cells are found to be bipolar or multipolar in form. The only other place where bulbous terminations, like those here described, are found is upon the cells of the sensory

ganglia of the cranial and spinal nerves. Furthermore, since the cells that give origin to this root have the form and arrangement of known sensory cells, Dr. Schneider justifiably concludes that the structures he describes are a proprioceptive apparatus.

STUDIES ON GROWTH

GROWTH OF GORILLA AND OF OTHER HIGHER PRIMATES

The material is not yet available on which to base a description of the prenatal development of apes in the way that can be done for man. Some fragments of this important story, however, have appeared and these have been collected by Dr. Adolph H. Schultz and he has supplemented them with a description of a well-preserved female gorilla fetus having a sitting height of 88.5 mm. and corresponding in development to a human fetus at the beginning of the fifteenth week. It is next to the youngest gorilla specimen thus far described. The fetus belongs to the Carnegie Museum and was kindly loaned for the purpose of this study by Dr. W. J. Holland.

Dr. Schultz finds that the African apes grow more slowly than man before birth, but much more rapidly during postnatal life, their final weight being attained in eight to ten years. Though having a shorter period of growth, they exhibit a much greater relative amount of growth change in body proportions than is found in man. The greatest differences in body proportions of the various higher primates are found in the limbs, whereas those of the trunk are much the same in apes and man. The trunk in lower primates is, of course, long and slender, but in apes and man it is proportionately broad and stout and even more so in gorilla than in man. As for the head, it decreases with advancing growth in proportion to the size of the trunk, in gorilla as well as in all other primates, attesting the relative precocity of the growth of the brain. Fetuses of both apes and man have extremely broad heads and the nose is as prominent in gorilla fetuses as in negro fetuses.

In general, it is found that the resemblance between the various higher primates is much greater in fetal than in adult life, fetuses being more uniform in regard to body proportions than adults. Of all the apes, Dr. Schultz finds, on the basis of the average and maximum deviation indices, that the gorilla resembles man most closely, both in fetal and in adult life. The chimpanzee ranks second in this respect, whereas the strictly arboreal orang and gibbon are much further removed. This is corroborated in the matter of the ischial callosities, acquirement of pigmentation of the skin, prominence of the nose, proportionate size of the external ear, form of hand and foot, and finally in his terrestrial mode of life. It is interesting to note that the hand and foot of gorilla in late fetal stages possess in moderate degree most of the features typical of arboreal primates. Even in infants these structures are not yet nearly as much modified for terrestrial use as in adults. Furthermore, in the adult gorilla the arms are proportionately shorter and the legs relatively longer than in the young animal. Dr. Schultz concludes from this that while attaining its unique colossal size, rendering tree life impracticable, the gorilla followed an evolutionary trend similar to that which was most likely taken by man's ancestors.

DEVELOPMENT OF THE HUMAN FOOT

The studies of Dr. W. L. Straus jr., dealing with the ontogenetic changes occurring in the skeleton of the human foot and leg and their comparison with the conditions found in the lower extremities of other primates, were referred to in my last report, in Year Book No. 26. Since then the completed report of these important observations has appeared in the Contributions to Embryology.

STUDIES IN ANATOMY OF THE ADULT

STRUCTURE OF THE THYROID GLAND

By placing fresh thyroid glands in a solution of acetic acid and glycerine (Siehler), followed by immersion in hydrochloric acid, Dr. W. F. Rienhoff found that the right amount of maceration had occurred to render their dissection under the binocular microscope possible. With this improved method he was able to remove the connective-tissue framework and demonstrate the configuration of the parenchyma—that is, the masses of epithelial follicles. Though the gland possesses no true lobulation, its follicular substance is much indented and irregularly fissured by connective-tissue septa containing the blood-vascular and lymphatic equipment with which the gland is richly provided. In this subdivision, however, of the essential gland tissue, the continuity of the latter is to a large extent preserved by means of numerous annectent parenchymatous bars of varying size and shape. Further points of interest are the absence of interfollicular cell rests and that the lymphatic system does not open into sacs. Dr. Rienhoff included in his studies both normal glands and exophthalmic specimens. The chief difference that characterizes the latter is the larger size of the constituent follicles, the number apparently not being increased. A preliminary account of this study has been published and at the present time drawings and control wax-plate reconstructions are being made for the purposes of a complete description of the anatomy of the gland.

RACIAL VARIATION IN VASCULAR PATTERN

An attempt has been made by Dr. C. F. DeGaris, in cooperation with Dr. W. B. Swartley of the Jefferson Medical College, to determine if there are diverse arterial patterns that characterize white as opposed to negro stock, and whether a greater diversity of patterns is present in one stock than in the other. The reader of these reports will already be familiar with the work of Evans, Sabin, Heuser, and Woollard, showing that an arterial pattern is the ultimate product of a series of environmental factors interacting upon the primitive endothelial net. Such a pattern is not to be regarded as a morphological goal in and for itself, but rather as an expression of vascular response to the functional demands and adaptation to the structural conditions of the region. The study of the pattern of the axillary artery and its branches, as made by Dr. DeGaris and Dr. Swartley, is therefore of interest, not only with respect to the artery itself, but also the preceding embryological events and structural factors concerned in its production and of which it is a record. On the basis of a study of 512 dissections, equally distributed between negroes and whites, they describe 23 pat-

terns of branching. Two of these can be selected as distinctly the prevailing types. One of them is more common for whites and the other for negroes. If these two types are accepted as norms and all other patterns as variations, it is found that variations are more frequent in negroes than in whites and in the direction of fewer branches. It is interesting to note that there are no axillary patterns distinctly peculiar to the right or left side. There is, in fact, a tendency toward bilateral symmetry to the extent that a given norm or variation occurring on one side is commonly found on the other side, though usually in a modified form. The query with which these investigators started, namely, as to the existence of a difference between the negro and white races in these respects, is clearly answered in the affirmative.

ARCHITECTURE OF THE AMPHIBIAN KIDNEY

Two studies of the kidney have been previously mentioned in these reports. Dr. Rienhoff (1922), studying the development of this organ in chick embryos, demonstrated the high degree of specificity that exists in nephrogenic tissue and that small transplanted embryonic particles tend to acquire their predestined form in spite of foreign environment. Dr. Traut (1923) combining dissection with maceration in solutions of hydrochloric acid, was able to contribute to our knowledge of the structural unit of the human kidney. A method of maceration similar to that employed by Dr. Traut has been applied to the frog's kidney by Dr. S. G. Stewart, who was thus able to demonstrate the relation and distribution of the glomeruli and tubules, and also the form of the individual tubule. He finds that the proximal convolutions are uniformly restricted to the dorsal third of the kidney along with the collecting tubules. The distal convolutions, marked off from the former by tubular necks, lie chiefly in the ventral third and in the middle third are found the glomeruli. There thus exists in this kidney a topographical separation of its main functional elements. To the student of renal function it offers an opportunity of studying an organ in which the distal and proximal convolutions can be recognized under living conditions.

STUDIES ON THE GALL-BLADDER

Bringing together his results of several years' study of the development and the microscopic structure of the normal human gall-bladder, Dr. B. Halpert has completed in two important papers a description of this baffling reservoir. In one of them he traces the organogenesis of the gall-bladder from the stage of the 25-mm. embryo to fetuses of 130 mm. Comparing the muscular coat of the gall-bladder with the musculature of the duodenum, he concludes that it is homologous to the muscularis mucosæ of the duodenum rather than to the tunica muscularis. This is based on the closeness of the muscularis of the gall-bladder to the lining epithelium and its comparatively late appearance in development. Further evidence is provided by the fact that some of the glands at the neck of the gall-bladder penetrate the muscular coat, just as Brunner's glands perforate the muscularis mucosæ of the duodenum. This genetic relationship may explain why certain foreign stimuli, which cause an immediate and powerful contraction of the intestine, have no noticeable effect on the gall-bladder. In this

treatise there is included a useful summary of our present knowledge of the microscopic anatomy of the adult gall-bladder.

In another study Dr. Halpert deals with the "true Luschka ducts" and the "Rokitansky-Aschoff sinuses," concerning which there has been some confusion as to their origin and significance. He was able to demonstrate that they constitute two different structures. True Luschka ducts are of the nature, histologically, of aberrant bile-ducts. They are definitely duct-like, with a narrow lumen, and are usually lined with a lower columnar epithelium than that of the gall-bladder. Their supporting wall, in histological structure, resembles that of the intra-hepatic bile-ducts, consisting of cellular connective-tissue-fibers. They are only occasionally present and when present are most frequently seen in the hepatic part of the gall-bladder wall, along the edges of the fossa vesicæ felleæ. In the specimens where they were followed in serial sections, they could be traced as multiple ducts anastomosing with one another or with a bile-duct from the liver. In no case, however, were any of them found to be in communication with the lumen of the gall-bladder. In contrast to these aberrant bile-ducts, the "Rokitansky-Aschoff sinuses" are hernia-like outpouchings of the gall-bladder mucosa. They dip down into the muscularis or extend as finger-like evaginations through the muscular coat into the perimuscular layer. Judging from the 300 gall-bladders studied by Dr. Halpert, he concludes that outpouching of the mucosa only rarely occurs in the normal specimen. They are numerous, however, where structural changes have occurred in the wall of the gall-bladder, particularly where there is a general loosening and weakening of the contractile elements and widening of the intermuscular septa. The sinuses are characteristic for gall-bladders exposed to repeated and prolonged increased pressure from within. They appear to be a product of over-distention and are to be classed as pathological.

The observations of Dr. Halpert and others indicating the resorption of biliary constituents through the wall of the gall-bladder, and certain experiments which prove that bile becomes markedly concentrated while in the gall-bladder due to abstraction of water and possibly other materials, have made it necessary, before further progress can be made in tracing the pathways through which the absorption occurs, to know more in detail about the vascular equipment of the gall-bladder. There has been a particular need of better acquaintance with the lymphatic drainage of the gall-bladder wall. This need has been in large part remedied by Dr. W. L. Winkenwerder. Using Lee's method of ligation of the thoracic duct and consequent dilatation of the lymphatic vessels, he was able to obtain very complete retrograde injections with diluted india ink of the lymphatic vessels of the gall-bladder of cats. The injections were made on the living animal under anesthesia, the successful specimens being fixed, cleared and studied under the binocular microscope, either as a whole or in razor sections. In this way he has been able to demonstrate adequately how, starting with a delicate plexus in the subepithelial layer, the pathway can be traced through connecting vessels to a second plexus in the perimuscular layer, where a few valves begin to appear. From this the drainage extends through short, stout trunks, into a third or subserous plexus overlying the free portion of the

gall-bladder. This subserous plexus consists of large, rather straight anastomosing channels with many valves. Toward the cervical end of the gall-bladder these channels unite into straight draining trunks that lead to a group of lymph-nodes near the duodenum. Lymphatic trunks from the liver enter these same nodes, either independently or by first uniting with the trunks from the gall-bladder near their termination. In the cat, at least, there are no direct anastomoses between the lymphatics of the gall-bladder and the adjacent liver, which had generally been supposed to exist. With his familiarity with the vascular anatomy of the gall-bladder, Dr. Winkenwerder is prepared to study its absorptive functions and the part played by the lymphatics in such a capacity. Some experiments toward this end have already been made by him.

THE HUMAN ILIUM

Through a fellowship of the National Research Council, Dr. W. L. Straus jr. was enabled to spend the scholastic year 1926-1927 with Professor T. Wingate Todd of Western Reserve University, where he completed a metric study of the human ilium with respect to sex and stock (white and negro) modifications. He finds that male and female White pelvises are larger, on the average, than Negro pelvises of the corresponding sex in all of the absolute dimensions of the ilium. Also within one sex there are no stock-linked differences in iliac proportions, either in regard to the relation of one dimension to another or to larger bodily dimensions. It is hoped that Dr. Straus will extend this interesting work, here mostly limited to the ilium, to the whole pelvis and to the pelvises of other animals, which, though a great undertaking, would provide us with a better foundation for the determination of pelvic phylogeny.

EXPEDITION FOR OBTAINING WHALE MATERIAL

Doctors Huber, Langworthy, Schultz and Wislocki, together with Mr. Kellogg of the U. S. Biological Survey and Mr. Howell of the U. S. National Museum, during the past winter visited Cape Hatteras, North Carolina, and were successful in obtaining a large amount of material from freshly killed porpoises which, because of the extreme specialization of this marine mammal, is of great interest to the comparative anatomist. The material obtained includes the central nervous system, special sense organs, respiratory apparatus, and the reproductive tract, all of which were suitably fixed for future studies. The porpoise skull offers an opportunity for the study of variation in a markedly divergent type, and for this purpose 160 specimens were brought back by Dr. Schultz.

DEPARTMENT OF GENETICS¹

C. B. DAVENPORT, DIRECTOR

GENERAL STATEMENT

This is the twenty-fifth report of this Department and its predecessor, the Department for Experimental Evolution, the twenty-fifth report I have had the honor to make to the trustees of the Institution. A few paragraphs on the history of this Department seem appropriate.

Established by vote of the Board of Trustees on December 8, 1903, resident work was begun May 1, 1904; the Station for Experimental Evolution was formally opened June 11, 1904, with addresses by W. R. T. Jones, Governor of the Wawepex Society; John S. Billings, of the Board of Trustees; Franklin W. Hooper, Director of the Brooklyn Institute of Arts and Sciences; and Professor Hugo de Vries. The staff consisted of George H. Shull, plant genetics; Frank E. Lutz, entomological genetics; Miss Anne M. Lutz, cytological genetics; and the director, who tested Mendelian laws on poultry and canary birds. Mr. John N. Johnson, who this year retires on reaching the age limit, served from the beginning in the indispensable capacity of caretaker.

The early years of the Department were devoted to a reconnaissance, but we soon settled on poultry; *Oenothera* and *Lychnis* among plants; and *Drosophila*, *Gryllus* and *Coccinellids* among insects. Cytological studies on *Oenothera* were made by Miss Lutz, who in 1907 reported finding 14 chromosomes in *O. lamarckiana* and 28 chromosomes in *O. gigas*. At different times we have had the great advantage and stimulus of workers who have come to us for a few years, or many, to go on to other fields—such as R. H. Johnson, E. N. Transeau, J. A. Harris, R. A. Gortner, C. C. Little, H. D. Fish. Among the real advances made by the Department may be mentioned the theory of biotypes, the isolation of inferior biotypes from corn by inbreeding, and sex linkage in plants (by Shull); polyploidy of chromosomes (by Miss Lutz); double types of melanin and the ontogeny of pigment (by Gortner); mutation in parthenogenesis and control of sex reproduction in *Cladocera* (by Banta); inheritance of chemical properties of plant saps (by Harris); chromosomal mutations as a regular type of mutation in plants, especially *Datura* (by Blakeslee and Belling); demonstration of the male as the more metabolic sex (by Riddle); demonstration that the female protoplasm has special reducing properties (by Satin and Blakeslee); phylogeny of the chromosome complex (by Metz); discovery of a new type of maturation and nuclear division with sex control located in the egg (Metz); placing the law of growth of mammals on a critical basis (MacDowell); development of theory of multi-mutating genes and somatic segregation (Demerec); demonstration that Mendel's laws apply to many human traits physical and mental and that races differ in fundamental mental capacities as they do in physical traits (Davenport); demonstration

¹ Address; Cold Spring Harbor, Long Island, New York.

of differences in incidence of different types of social inadequacy in persons of different European stocks now in the institutions of this country (Laughlin); invention of a method of deriving an intelligence quotient from teacher's marks (Banker); demonstration of the mental basis of most differences in economic level (Estabrook); further demonstration of methods of inheritance of liability to cancer (Little and Strong).

The work of the year under review will have to be succinctly stated to save space. Belling finds that in *Lilium* the chromomeres are each composed of 4 elements, and regards it a good working hypothesis that these chromomeres are the genes. His basic studies on *Datura* chromosomes are still bearing fruit; very usable new mutations are being found in genes of *Delphinium* and *Drosophila* and new problems are arising in the study of the mutations of *Datura* which are finding an interpretation by appeal to the chromosomal conditions. Parthenogenetic *Cladoceras* yield new and physiological mutations which are mostly recessive in parthenogenetic strains. Progress is being made on the experimental modification of the germ plasm, following methods of Little and Bagg on mice, and the newer methods of H. J. Muller applied to flies. MacDowell has immensely improved the methods of studying the curve of growth of mice.

Into the basic nature of sex Miss Satin, working in collaboration with Dr. Blakeslee, has penetrated further, finding in female molds a higher content of sugars than in males. The determination of the sex ratio has been shown to be under the control of the egg in the fly *Sciara*, while in *Cladocera* it is determined by external conditions, acting on a special but still unidentified mechanism in the mother's ovarian cells. In pigeons new mechanisms have been found that regulate the time of sex-maturity.

In mice new genetic traits have arisen which will probably throw light on the inheritance of some complicated human ones. The study of race crossing in Jamaica is in press. This demonstrates that differences in somatic traits and in mental capacity follow the same laws and are inherited in similar fashion. A study is being made of the inheritance of a number of human traits, physical and mental. It is noteworthy that most of these problems on which we are now working had not been formulated a quarter of a century ago.

STAFF

The director, in addition to his administrative work in the Department, has completed, with Dr. Morris Steggerda and the assistance of a temporary corps of statisticians, an extensive study of race crossing in Jamaica. He has also carried on investigations into inheritance of goiter, athletic capacity and other human traits. Dr. A. F. Blakeslee, Assistant Director of the Station for Experimental Evolution, has pushed forward the work on *Datura*. He has been assisted in the summer by Professor John T. Buchholz, as group leader in pollen-tube behavior, Dr. Dorothy Bergner, as group leader in cytology, and Dr. J. L. Cartledge, group leader in pollen abortion. Dr. Blakeslee spent four months in Europe attending the Genetics Congress and gathering *Datura* material. Dr. H. H. Laughlin, Assistant Director of the Eugenics Record Office, besides carrying on a heavy correspondence, has continued the research into the inheritance of

racial ability, supported by funds from Mr. W. J. Salmon. He has been called upon by committees of Congress for eugenical advice, participated in the Immigration Conference held at Washington, January 19, and, as observer, in the Second International Conference on Emigration and Immigration, held at Havana, Cuba, March 31 to April 17, 1928. Dr. John Belling has been working at Berkeley, California, and continued his cytological work as a guest in Professor Babcock's department. Dr. A. M. Banta, ably assisted by Miss Thelma Wood, and during the summer with the cooperation of Dr. L. A. Brown, has continued his studies on parthenogenesis and sexual reproduction and control in Cladocera. He attended the Fifth International Congress of Genetics at Berlin, September 1927. Dr. M. Demerec has continued his work on mutating genes, and also attended the Congress of Genetics. Dr. C. W. Metz spent the winter in California collecting new forms of *Sciara*, and seeking, with Miss Mildred S. Moses, for an interpretation of the new and remarkable genetic complications in sex-control in that genus.

Dr. E. C. MacDowell has carried his studies of the growth curve of mice to the later stages, and has discovered new important mutations in mice. He attended the Genetics Congress, was guest at the laboratories of the medical school at Rochester, New York during 3 weeks, and spent much time in preparing the annual exhibit at Washington. Dr. Riddle has continued his studies of the effect of endocrine secretions on maturity of the sex glands of pigeons; also he is working with Dr. F. G. Benedict, of the Nutrition Laboratory, in a cooperative study of basal metabolism of strains of pigeons that differ in thyroid activity. Miss Edith Banta has continued as technical assistant in this research.

Dr. Howard J. Banker has perfected his analysis of teacher's marks as a measure of intellectual capacity and has begun to apply this criterion to specific pedigrees in a study of inheritance of intellectual traits. Dr. Estabrook has been working on his report on the Southern Appalachian mountaineers.

The archives of the Eugenics Record Office have been in charge of Miss Alice Gould. The computing room has continued in immediate charge of Miss Catherine Carley. The gardens and greenhouses have been in charge of Mr. Amos G. Avery. The breeding of mice has been looked after by Miss Elizabeth Lord, Mrs. Harriet L. Smart and Miss Dorothy Newman. The pigeon houses have been in charge of Dr. Riddle and Miss Marguerite Comunale. Miss Florence L. Barrows has served as librarian, Miss Margaret B. Chambers as artist and histologist, and Miss Mabel L. Earle as library abstractor.

The facilities of the Department have been used by various investigators. Professor D. D. Whitney, of the University of Nebraska, is working at the Department during the summer of 1928 on male production in Rotifers. Professor Vasil Obreshkove, of St. Stephen's College, studied the basal metabolism of Daphnids. Professor John T. Buchholz worked during the summer on pollen-tube growth in *Datura*. Professor W. H. Gates of the University of Louisiana investigated during the summer of 1928 the heredity of the shaker mutation and the growth of mice.

The Eugenics Record Office has been used by various outside investigators. Dr. George Draper, head of the Constitutional Clinic of the Presbyterian Hospital, arranged to have several hundred pages of abstracts copied for the purposes of the clinic. Charles V. Green, now of the University of Michigan, and working under a grant of the Research Committee of the American Medical Association, used the records as a starting point for investigations into inheritance of hæmophilia. Under a grant from the Eugenics Research Association Miss Dorothy Permar, of the Michigan State Agricultural College, made a study of mate selection, based on the records of the Office.

DETAILED REPORTS ON CURRENT INVESTIGATIONS

THE GERM PLASM

THE CHROMOMERE AND THE GENE

The prophetic speculations of Weismann and the classical researches of Morgan, Sturtevant, Muller and Bridges at Columbia University have made necessary, on theoretical, statistical and genetical grounds, the hypothesis of the gene as a particle that acts differentially in guiding development. It remained to identify this particle, visually.

That the chromosomes are sometimes made up of smaller bodies has been known for some years and the name of chromomeres has been applied to these smaller bodies. The advanced technical methods of Belling have elevated the chromomeres to the position of regular chromosomal constituents. He has recently been able to carry the analysis of these bodies further than has hitherto been possible.

A special technique of staining has been worked out that has made this possible. Belling's smear preparations have been fixed in a chromacetic-formaldehyde mixture in the proportion of 1:10:16 or 1:10:8, with more formalin than in the mixture used by S. G. Nawashin. The mixture with the greater proportion of formalin was found the more useful for chromomeres requiring the more rapid fixation. Dr. Belling reports further as follows:

"Iron-brazilin, as used by Hickson, was found to be the stain required; though it took some months to perfect its use. Its main advantage is that all the staining operations go on in 70 per cent alcohol. With 24 hours in iron alum, this stain gives dark threads at pachyphase,¹ the chromomeres being stained black and the rest of the thread yellowish. There is a double staining effect, the chromosomes being brown or black, and the cytoplasm light pink. Cedar oil, used as a clearer, prevents shrinkage. This method gave excellent preparations with over twenty species of monocotyledons and dicotyledons. For most stages they are superior to the best iron-acetocarmine slides, though they take two days to prepare, instead of two minutes. It is anticipated that this new method will open up several paths of research with bivalents at the reduction division.

"*Chromomeres*—The iron-brazilin method just described was found essential for the proper study of the chromomeres, and it was for this purpose that time was spent in perfecting it. The first question naturally was

¹ Belling suggests the use of the terms "leptophase," "zygophase," "pachyphase" and "diplophase" in place of "leptoten stage," "pachytem stage," etc.

whether the chromomeres were sufficient in number to correspond to the genes. It was found that the smallest chromomeres seen were so near the limits of microscopical separation (0.2 micron) that if they were any smaller they would tend to run together (optically, not in reality). In iron-acetocarmine, the chromomeres were only visible when special care was taken in the preparation. They appeared nearly uniform in size in *Alöe*, and could be counted. A count in *Alöe purpurascens* gave 1,240 for the number in the cell at pachyphase. All were about twice as broad as long. When stained with iron brazilin, however, the chromomers were especially sharp. They even showed diffraction color when examined with an objective of 0.3 aperture, as do certain diatoms. Preparations of *Alöe* in iron-brazilin seemed to show more chromomeres, and showed the longitudinal division of each. In *Lilium*, the preparations stained with iron-brazilin and mounted in thick cedar oil were superior to iron-acetocarmine preparations, since they were free from granules. The chromomeres of *Lilium* in the pachyphase and preceding stages were larger than those of *Alöe*, and were most favorable for observation. The pachyphase has the appearance of a row of beads (each with a light band down the center) formed of jet, amber, yellow glass, and colorless glass. These chromomers, though larger, are as numerous as those of *Alöe*, perhaps more so, for they show different sizes, some of them being about half the size of the others. The leptophase chromomeres are about as broad as long. Since the pachyphase chromomeres are twice as broad as long, and are divided longitudinally in all aspects of the thread, it follows that they are quadripartite. It can then be regarded as a good working hypothesis that the chromomeres are genes, with a more or less thick envelop of stainable substance in different species of plants.

"That the chromomeres observed by this method are not artifacts, the following considerations would seem to show.

"(1) When fixed for much too short a time, only the outer part of the cell—away from the glass slide—shows chromomeres.

"(2) With a weakened fixative (Flemming's solution), used several times before, only those cells show distinct chromomeres which had broken cell-walls.

"(3) The same was the case with iron-acetocarmine if too little liquid was used.

"(4) In the same species of plant, the chromomeres are of the same size and number in preparations treated with iron-acetocarmine, or with Flemming's solution, or with chrom-acetic-formol.

"(5) In paraffin sections of anthers of *Alöe*, fixed with all precautions, the chromomeres, though less distinct, are of the same numbers and sizes as in smear preparations.

"(6) With the fixative and stain described above, used with care, chromomeres are seen in all parts of the threads in all cells which have not been injured too much in squeezing, or covered with a piece of anther wall."

STUDIES ON CHROMOSOMES

SPIRAL BIVALENTS

In studying this subject about 20 species of flowering plants, mostly monocotyledons, including the *Lilium* worked on by Dixon, author of the term "strepsitene," Belling finds no proof that the homologous chromosomes of any bivalent form corkscrew spirals, at or after the diplophase.

On the other hand, there are abundant proofs that they form chiasmas and nodes. Belling reports further:

"The surest way in which the presence of corkscrew homologues could be proved would be by observations, when both strands of each homologue are traceable. Belling has not found such corkscrew homologues. When both strands are traceable, nodes are found, not corkscrews; and at all or most of the nodes there are chiasmas. If the two strands of each homologue are not distinguishable, as is often the case in plants, the presence of a corkscrew at any stage could be proved by showing that the two homologues are not fused at any point; that is, that there are no nodes. This early absence of nodes has not yet been observed. The presence of nodes, when the two strands of each homologue are not clearly separable under the microscope, leads naturally to the assumption that the junctions are chiasmas; as they are seen to be when both strands are traceable."

Hence Belling concludes:

"In the twenty species studied, that bivalents forming corkscrew spirals do not occur; but that the bivalents show nodes (chiasmas) connecting the two homologues at one or more points."

CALCULATIONS OF CROSSING-OVER FROM NUMBERS OF NODES

"This calculation only applies to fairly long chromosomes; for in short chromosomes (as in *Datura*) the nodes often disappear before metaphase—it is not known how. Such a calculation has already been made for the long chromosomes of *Hyacinthus*. The species of *Lilium* so far investigated have 12 long pairs of chromosomes. Calculation, with nearly a hundred bivalents, showed in *Lilium* that there would have been 31 per cent of the resulting chromosomes with no crossing-over (segmental exchange), 48 per cent with crossing-over at one point only, 19 per cent with two points of crossing-over, and 2 per cent showing three points of crossing-over. Similar counts of nodes are being made in *Alöe*, *Kniphofia*, and *Agapanthus*; in iron-brazilin preparations, which show these stages excellently."

CHROMOSOMES OF *RHÆO*

"Clear preparations of the metaphase and earlier stages of *Rhæo discolor* have been made with iron-brazilin. In the thousands of metaphases examined in the past two years, no bivalent has been seen. In conformity with this, no diplophase has been seen to occur. There is a contraction stage, but the writer has not yet been able to distinguish leptophase from a possible pachyphase. Presumably pachyphase is absent. The early stages closely resemble those of *Oenothera*, of which iron-brazilin preparations are clear and easily obtained. One row of chromomeres is to be seen at leptophase."

A WORKING HYPOTHESIS FOR SEGMENTAL INTERCHANGE

"If there is no corkscrew stage at or near diplophase and the nodes are seen as soon as the chromosomes open into loops after pachyphase, then a working hypothesis is required for segmental interchange which does not involve the formation of corkscrew spirals. If there is no twisting, Janssens' hypothesis requires alteration. Belling has assumed that the stretching at leptophase results in the genes (chromomeres) getting out of the range

of mutual attraction, though still connected by neutral substance. Such a point in the leptophase thread is said to be the locus of a *break*. Breaks may be assumed to take place at random, but not to be closer than a certain average distance, for obvious physical reasons. The breaks are regarded as independent in the two strands of each homologue at leptophase. At zygo phase such breaks may or may not coincide in any two of the four strands. If they do coincide at any point, they may on joining either form two straight strands as before, or may form a chiasma. If the chance for the breaks coming together in any two of the four strands is $1/x$, and if c is the percentage number of crossings-over between any two adjacent genes, then, with the most probable assumptions, it can be shown that $1/x$ is equal to $c/100$."

MUTATIONS

GENE MUTATIONS IN DELPHINIUM

Owing to the fact that *Delphinium ajacis* is naturally insect pollinated, self-pollination is not so common as cross-fertilization. On the principle that cross-fertilized species are liable to accumulate recessive characters that can be brought out by selfing, Demerec was led to expect that selfing *Delphinium* would reveal different heritable modifications. Accordingly he selfed several lines of *Delphinium* and several new characters appeared. Demerec reports on the most striking of these, as follows:

"*Male-sterile*—The development of the pollen of male-sterile plants stops before the pollen reaches maturity, causing its sterility. The character appears to be inherited as a single Mendelian recessive. Male-sterile plants, however, produce flowers with a few anthers with partially good pollen, and also branches with normally developed and fertile flowers. Upon selfing of partially fertile flowers wild-type and male sterile plants were obtained in variable ratios. All the evidence indicates that the male-sterile character might be determined by a mutable gene.

"*Fasciated stem* character was followed for three generations and it proved to be inherited. Fasciated plants, however, appeared in small numbers in segregating pedigrees. Since wild-type branches can be frequently observed on fasciated plants it is very probable that fasciated character also is determined by a mutable gene."

MUTABLE GENES

As stated in previous reports (Year Book 1925, p. 36; 1926, p. 33), Demerec has discovered that in *Drosophila virilis* the miniature-alpha wing character frequently mutates (reverts) to its wild type allelomorph. During the past year he has conducted an experiment to determine whether the changes in miniature-alpha occur both in the direction of constant miniature and of constant wild type. Of a highly mutable miniature-alpha line 68 flies were tested. Of them 41 were mutable miniature-alpha, 23 were wild type and only 1 was constant miniature. In the line tested, it appears miniature-alpha may mutate to constant miniature, but does so less frequently than to constant wild type.

GENE MUTATIONS IN DATURA

The search for gene mutations goes on in *Datura*. They are important as tags, not merely of the entire chromosomes but also of the parts of

chromosomes that enter into new combinations. During the past year, Blakeslee reports that—

"Several new Mendelian characters have been discovered from collections in nature, from spontaneous mutations and from plants subjected to different treatment.

"More spontaneous gene mutations have occurred in a haploid 1A than in later generations in Line 1A derived from this haploid. Thus of 316 F_1 plants tested, 7 (2.2%) were recessive for new genes; while of 568 plants in F_2 and later generations similarly tested, none (with a single possible exception now under investigation) has been heterozygous for new genes. The cause for this apparent difference is not yet clear.

"One of the new genes is a dominant ('male-sterile') and causes the complete failure of pollen development but leaves the egg cells viable.

"A recessive gene obtained from a collection in Baltimore prevents pairing of chromosomes at reduction and renders plants homozygous for the factor sterile in both eggs and pollen.

"The gene for the character 'swollen' had been previously reported apparently to revert to normal in the heterozygous condition. By making reciprocal back-crosses from different flowers, it has been discovered in one case that the pollen failed to transmit the gene, while it was transmitted by the egg cells.

CHROMOSOMAL MUTATIONS IN *DATURA*

The study of the types of mutation that are due to abnormalities in the number of entire chromosomes, to abnormal unions of segments of chromosomes or to interchange of segments between non-homologous chromosomes, involves constant study of the cytological conditions that occur in the mutants of *Datura*.

"Various new chromosomal types have appeared in our cultures during the year, in some of which the cytological relations have been determined. One of these is Thistle which is a secondary ($2n+1$) type complementary to Mutilated. These two secondaries of *Echinus* are both vigorous in growth and reproduction and hence will be of value in analyzing genetic situations in which tests with a primary and its two secondaries are necessary."

Dr. Blakeslee reports further:

"It has been reported previously that certain races, called 'B whites,' since they give trisomic ratios from two different primaries, show, in F_1 's with our standard Line 1A, rings of 4 attached chromosomes. The chromosomes involved in these 'B white' rings of 4 have been determined by inheritance ratios of the factors for white located in one of the two pairs of chromosomes involved in the ring. The hypothesis that in the origin of 'B white' races interchange of segments between two non-homologous chromosomes had taken place has been confirmed by several lines of evidence. We have found, for example, that when a primary which contains, as an extra, one of the chromosomes involved is rendered heterozygous for a 'B white,' the ring of 4 is broken and a chain of 5 chromosomes takes its place, and that when the secondary of such a primary is heterozygous, the ring is increased to 5 members. The resulting configurations in primaries and secondaries, therefore, offer a method of determining the chromosomes involved in other attached sets of chromosomes.

"So far we have studied configurations in F_1 's between our standard Line 1A and 87 different lines from nature. Of these, 46 (or slightly over half) have shown attachments of 4 chromosomes either in rings or chains. In 6 cases there were found two such attached groups of 4 chromosomes, leaving only 8 bivalents instead of 12 bivalents expected in normals. One case has been found in which the race induces in F_1 's an association of 4 chromosomes not attached end to end but with two closed bivalents joined together like two links of a chain. Judging by the size relations, it is probable that there are at least 8 distinct types in the peculiar configurations so far discovered. There are possibly many more since many chromosomes are of the same apparent size. It should be possible, however, by breeding behavior and by study of chromosome attachments in $(2n+1)$ forms, heterozygous for lines inducing these attachments, to discover the specific chromosomes involved in special types of configurations.

"Information regarding differences between biotypes of a single species in nature, of which we have several hundred, as well as between different species, has been accumulating from study of F_1 hybrids with standard races. Among the F_1 's between Line 1A and nearly 300 races so far studied, about 23 per cent show definite percentages of aborted pollen grains and ovules.

TABLE 1—Distribution of pollen types in *Datura stramonium*

	No. of lines	Line 1 type	Line 7 type	Other types
United States:				
Massachusetts.....	25	19	6	0
Virginia.....	43	40	3	0
Other States.....	48	43	5	0
West Indies and Central America.....	19	12	5	2
South America:				
East Coast.....	16	16	0	0
West Coast.....	34	5	0	29
Europe.....	26	24	2	0
Africa.....	17	8	9	0
Asia.....	5	5	0	0
Japan and East Indies.....	8	8	0	0
Australia.....	4	2	2	0
Botanic Gardens, etc. (includes commercial).....	47	41	6	0
Totals.....	292	223	38	31
Per cent.....	100.00	76.37	13.02	10.62

"Something can now be said in regard to the geographical distribution of pollen types, as seen from Table 1. In Brazil, for example, on the east

coast of South America, all the races collected were of the Line 1 pollen type, while in Peru on the west coast all the races tested were of a type inducing 25 per cent aborted pollen. In Chile, both this type and the Line 1 type were found.

"Attempts are being made, with some success, to locate the chromosomes involved in the different types of pollen abortion.

"F₁ hybrids between different species of *Datura* (7 different species have given hybrids in one or more combinations) show a similar abortion of pollen and attachment of chromosomes found in inter-racial hybrids—only a condition more extreme. It is believed that the present study is giving a clue to the differences which separate varieties and species, and points to a method of evolution."

CLADOCERA MUTATIONS IN PARTHENOGENESIS

SELECTION STUDIES UPON MUTATIONS IN PARTHENOGENESIS

Cladocera are exceptionally favorable material for the study of mutations. They are easily and inexpensively reared; they produce a parthenogenetic generation each week; and, in parthenogenesis, chromatic reduction does not occur, so that all descendants of a given female are genetically precisely like the original mother (except as a mutation occurs). Moreover, mutations do occur in these animals and they may be induced to have sexual reproduction, thus permitting the studies on inheritance in parthenogenesis to be linked with the numerous studies on inheritance in sexual reproduction in other organisms.

THE SEX INTERGRADE CHARACTER

As described in earlier reports, strains have developed in the daphnias, *Simocephalus exspinosus* and *Daphnia longispina*, under Banta's breeding, in which the secondary sex characters are intermediate. Selection for intergrades in these species is now completed. Banta's results may be thus summarized. The average degree of sex-intergradedness is subject to dominant mutative change—selection is effective in increasing or decreasing the degree. Extreme sex intergrades went sterile, but less extreme lines maintained their quality indefinitely. The low selected lines showed progressively lower degrees of intergradedness. In all cases the change is not gradual but by definite steps of appreciable magnitude. Return selections yielded equally marked changes in grade. An example of the abruptness with which these mutations arise is that of a female of the low sex intergrade line, herself graded 0.06, who had 3 daughters, whose progenies were studied. One of these progenies averaged about 0.06. The other 2 lines were of much higher grade; averaging 0.90 in one case and 0.96 in the others.

EXCAVATED HEAD CHARACTER

Another mutation affects the outline of the head of *Daphnia*. This, also, by selection, is continued in a high and in a low line. Return selection has proceeded more slowly than in the case of sex intergrades, since the character is less subject to mutation. Two lines of return selection have yielded mutations in the direction in which selection was being sought; but in one case in a selection to increase the character a strong dominant mutation

occurred in the direction opposite to that sought, and this low line has been maintained for 18 generations to the time of writing.

Just because of the great numbers of generations of daphnids followed, mutations (even if slight) are not infrequently found; and by selection of such mutants in a given direction a character may become greatly changed in degree of expression. It seems probable that slight mutative changes, progressing along a given line, occur in all organisms and enable advance to be made by the careful breeder and selector.

THE PHYSIOLOGICAL CHARACTERISTICS OF A CLONE

Banta reports—

"It is a matter of general observation in our cultures that a clone is usually quite uniform as regards general vigor and reproductive capacity, and Miss Kathryn Ordway, who studied this matter on our material, finds this opinion entirely confirmed by the collation of extensive statistics on age at the beginning of reproduction, numbers of young per brood, brood interval, etc., for several different series of a clone."

MUTATIONS OF PHYSIOLOGICAL IMPORT APPEARING IN PARTHENOGENESIS

Our stock contains lines of a number of species which have been in the laboratory and have had only parthenogenetic reproduction for long periods of time, some of them for nearly 17 years. Banta reports the following general findings of interest:

"Most of our lines continue from year to year without detectable change in their general reproductive vigor.

"However, in certain of our lines of *Daphnia longispina* and of one of our types of the *Daphnia pulex* group changes in reproductive vigor have been noticed. A line sometimes suddenly shows a reduced vigor. By carefully selecting for a time to obtain the most vigorous individuals, we frequently, sooner or later, obtain a normally vigorous individual. Such an individual ordinarily produces young which in turn have normal reproductive capacity and the restoration of vigor is thus attained. Sometimes increased vigor appears without any conscious endeavor to select for it, but this is less frequent and occasionally lines are lost.

"In our studies with sexual reproduction in Cladocera we have demonstrated that clones sometimes carry apparently many cryptic and quite unsuspected recessive factors. These factors may produce lethal effects, sterility, reduced vigor, increased vigor, 'thermalness,' or other physiological effects among the sexually produced young from a clone inbred. In sexual reproduction offspring resulting from cross-breeding two weaker clones, or from inbreeding a weaker clone, range all the way from non-viable individuals to individuals with excellent reproductive vigor. The obvious interpretation of this result is the occurrence of recessive factors, various combinations of which produce a diversity of genotypes and phenotypes. The assumption of factors of like import, but less frequent in occurrence and dominant instead of recessive, readily accounts for changes in reproductive vigor within a clone and we believe such is the correct interpretation of all such cases which are not due (as some of them obviously are) to unfortunate cultural conditions.

"Such reductions in vigor, which many workers have encountered in clones of Cladocera, rotifers, protozoans, etc., after longer or shorter

periods of parthenogenesis, have generally been explained as produced by the necessity for sexual reproduction, changed nuclear-cytoplasmic relations, etc. The application of genetic findings to explain changes in vigor seems to us to remove the mystery attached to this type of phenomenon."

INHERITANCE IN SEXUAL REPRODUCTION OF CLADOCERA

Studies of inheritance of excavated head, sex intergrades and short beak have been continued. New characters, called round-head and flat-head have appeared. The thermal gene is apparently recessive, cloaked in parthenogenesis, and becomes patent by sexual inbreeding. Mated to wild type the F_1 progeny are non-thermal.

While several dominant mutations have arisen in daphnids during parthenogenetic reproduction, it is probable that many more recessive mutations have occurred, but they are not ordinarily detectable in parthenogenesis. They are revealed by sexual reproduction. These that Banta has already discovered are largely of a physiological nature, such as lethals, sub-lethals, sterility factors, factors influencing general physiological vigor or reproductive capacity and thermal-resistance. Presumably these mutations accumulate during the parthenogenetic generations, and the greater the number of such generations the greater the number of accumulations of such cryptic factors. Accordingly the results are found as shown in Table 2. After a long series of parthenogenetic generations the hatchability of sexual eggs and high fertility of progeny decline, while sterility increases from 14 to 67 per cent.

TABLE 2—Data on hatchability of sexual eggs and sterility of hatched young of *Cladocera* clones inbred after different numbers of parthenogenetic generations

		Sexual eggs			Sterility		Excellent fertility	
Line	No. of parth. gen. before inbred	No.	No. hatched	Per cent hatched	No.	Per cent hatched	No.	Per cent hatched
1,621....	1	177	78	44	11	14	17	22
1,622....	1							
1,217....	136	376	34	9	7	21	10	29
XI.....	356	193	21	11	14	67	2	12

Sister clones arising from sexual reproduction vary greatly in physiological, including reproductive, vigor and in mutative characters, in striking contrast to the "identical twin" similarity of clones arising by parthenogenesis. Miss Ordway has accumulated statistics on this point.

Additional results have been obtained by Banta in his study of the consequences of introducing one of the oldest of his parthenogenetic lines of *Daphnia longispina* (Strain XI) one or more times as grandparent. At present it appears that when only one grandparent is of Strain XI hatch-

ability is 34 per cent and sterility is 15 per cent; with two grandparents the percentages are 7 and 39 respectively; with three grandparents 14 and 71, with four grandparents 7 and 100. Thus hatchability decreases and sterility increases with the number of Strain XI grandparents.

EXPERIMENTAL MODIFICATION OF THE GERM PLASM

The induction of mutations is a technical procedure of the greatest importance, since it makes possible the analysis of the chromosomes and provides means for hastening evolutionary change. Of course, the effects of the mutation-inciting agent are limited by the constitution of the germ-plasm.

While reports of partial success in the induction of mutations have appeared from time to time, they have not until recently been satisfactorily confirmed, nor have they been followed up by the observers. Using *Drosophila* Mayor found that X-rays may cause irregularities in the chromosomal complex. In this Department, Little and Bagg (Year Book for 1921, pp. 112-113) reported the occurrence of mutations in mice after the use of X-rays. In 1921 Blakeslee and Gager cooperated in the application of radium to *Datura* and the mutation "Nubbin" arose after that treatment.

The important effect of radiation on germ plasm has been emphasized by the extensive experiments of Muller in subjecting *Drosophila* to X-rays. Dr. Demerec, working in cooperation with Dr. E. G. Anderson, formerly of this Department and now of the University of Michigan, has made experiments applying the technique of Muller to *D. melanogaster*. He reports as follows:

"The flies were exposed for 12 minutes at a distance of 20 cm. to the unfiltered rays generated by a Coolidge tube at 130 kilovolts and 5 milliamperes. Males and virgin females from *sc cv v f* and *ec ct g* stocks were treated and matings were made in all four possible combinations between untreated flies of one stock and the treated flies of the other stock. Almost all treated females were sterile. Treated males produced a small number of offspring. In 331 treated and as many untreated X-chromosomes the following genetic changes were observed:

	Treated	Untreated chromosomes
Lethals.....	32	1
Deficiency.....	1	
Visible mutants.....	5+ (1 ?)	1 (?)

"The results of experiments indicate strongly that the X-ray treatment was effective in producing heritable changes. Visible characters included the reappearance of forked bristles and miniature wings, which characters were previously known. The other visible characters were: twisted abdomen, condensed veins, crippled, and the extra veins.

"In addition to the above mentioned sex-linked changes five autosomal mutations were found, for which, however, it has not been possible to determine whether they originated in the untreated chromosomes.

"An analysis of the data showed that miniature, twisted, condensed and crippled originated in the treated males, deficiency and forked originated in F_1 females (one generation after the treatment) and the extra vein character was found in a single male (two generations after the treatment). For extra veins, however, it can not be said with certainty that it occurred in the treated chromosome."

In 1921 in cooperation with Dr. Gager, of the Brooklyn Botanical Garden, efforts were made by Blakeslee to induce genetic changes by use of radium. Following treatment of a single capsule they obtained (a) 17.7 per cent chromosomal mutants in the offspring (untreated parents give an average of less than 0.5 per cent); (b) a new compound chromosomal type (Nubbin) which was formed apparently by the fracture of three different chromosomes and the reattachment of the separate halves of one to a half of each of the other two, (c) two recessive genes from only 18 F_1 parents tested by selfing. The appearance of new genes in 11 per cent of the individuals tested suggests a high rate of mutation in comparison with the extreme rarity in comparable material discussed in earlier paragraph.

"Dr. Gager, on account of administrative duties, has been unable to continue the radium experiments, but during the summers of 1927 and 1928 Dr. Buchholz continued the work, raying pollen and pollen tubes. He has established a graded effect upon speed of pollen-tube growth proportional to the intensity of radiation to which the pollen was exposed. From about 50 offspring from treated parents, we have so far found two distinct forms, of which one appears from attachment of chromosomes to be a compound chromosomal type related in its method of attachment to Nubbin. Three normal-appearing plants produced 50 per cent aborted pollen grains, and one plant 25 per cent. Of seven normal-appearing offspring from the treated parents so far examined cytologically, two show configurations of attached chromosomes, one a ring and the other a chain of 4. The F_2 generation is now growing in the field but is not yet recordable for adult characters. Apparently one of the parents, however, was heterozygous for a gene affecting seedling characters.

"Another method of treatment, carried out by Blakeslee, which apparently has caused the induction of genetic changes, is wounding the young capsules at flowering. Capsules were also injected with chloral hydrate but, since similar results were obtained from pricking with a needle, the effects can be attributed to wound reactions. Succeeding wound treatment, the following variants have been obtained, (a) several somatic mutations involving deficiency of a labeled chromosome derived from the pollen parent; (b) a 'double-diploid' condition in pollen mother cells, *i. e.*, a doubling of chromosomes but with bivalents instead of quadrivalents; (c) two new recessive genes, one of which is recognizable in the seed pan; (d) two undetermined types (possibly chromosomal), one of which frequently reverts to normal."

PHYSIOLOGICAL SELECTION OF EFFECTIVE GAMETES

DEFECT IN POLLEN AND POLLEN-TUBE GROWTH IN DATURA

The phenomena of sterility in plants have long been known. That defect in pollen, or in pollen-tube growth, is responsible for wide deviations from expected statistical frequency of the different types of offspring from a mating was suggested by Correns. Buchholz by the invention of a new method

of dissecting away the cortex of the style has opened the way for direct observation of the pollen tubes *in situ* in relation to developmental selection. He has in press a joint paper with Blakeslee on the growth of 1n and 2n pollen tubes in the styles of the balanced series 1n, 2n, 3n and 4n. They report—

“The failure of the cross $2n \times 4n$, when the 4n is the pollen parent, has been found to be due to bursting of pollen tubes. Bursting of pollen tubes has been found to be the primary cause of the failure to obtain inter-specific hybrids in certain combinations. The block to crossability between species is a matter of considerable evolutionary importance and demands further study. Study of the influence of single extra chromosomes and halves of chromosomes upon pollen behavior has been continued. The condition in the primary $(2n+1)$ type Rolled and its two secondaries, Sugarloaf and Polycarpic, are especially interesting. Tubes containing an extra unmodified Rolled chromosome generally burst before reaching the ovary; tubes in which the extra chromosome consists of the doubled Polycarpic half of the Rolled chromosome fail to germinate; tubes with the extra chromosome composed of the doubled Sugarloaf half grow at a reduced rate but reach the ovary. The prediction from these results that Sugarloaf would be transmitted through the pollen when competition was reduced by scanty pollinations has been fulfilled.”

CROSS STERILITY IN MAIZE

Demerec has been carrying on studies in albinism of different varieties of maize in cooperation with Professor R. A. Emerson, of Cornell University. He has noticed that in the case of a rice-popcorn variety all attempts of cross-pollinations were highly unsuccessful when the rice-pop plants were pollinated with a mixture of their own pollen and the pollen taken from other varieties of maize. Demerec reports further as follows:

“To determine the extent of this differential fertility an experiment was made in which several plants belonging to different varieties of maize including popcorn were pollinated with the same mixture of popcorn and not popcorn pollen. The varieties used in the experiment differed in endosperm characters in such a way that in each case it was possible to distinguish seeds obtained from popcorn pollen from those obtained from not-popcorn pollen. The results of this experiment indicated that a differential fertility in favor of popcorn pollen existed only when popcorn was the female plant.

“The observed differential fertility in favor of rice-pop pollen might have been caused by a difference in pollen-tube growth. If rice-pop-pollen tubes grow faster on the rice-pop silks than the pollen-tubes of other varieties of maize they would reach the ovules sooner and have a better chance to accomplish the fertilization. That explanation, however, was rendered improbable by the observation that rice-pop ears, one side of which was self-pollinated and the other side pollinated with the pollen taken from other varieties of maize, had very few or no seeds on the cross pollinated sides. On these ears there was no competition between the pollen-tubes but at the same time cross fertilization was not accomplished. The same was true when rice-pop ears were pollinated with not-rice-pop pollen only. Seven such ears gave 18 seeds instead of about 4,000, indicating that this rice-popcorn variety was almost sterile to the pollen of other varieties

of maize. To determine the extent of that sterility the rice-popcorn was tested with fourteen strains of maize and in all cases it was sterile.

"In F_2 generations from crosses between this rice-popcorn and several varieties of sugary corn, a significant deficiency of sugary seeds was observed. The occurrence of deficiency of sugary seeds in rice-pop crosses has been known for a long time and extensively studied by R. A. Emerson and also by D. F. Jones. Both of them reached the conclusion that a factor linked with sugary was responsible for that deficiency, which factor prevents the fertilization with sugary sperm in certain genetic environments. The results of our experiments agree with Emerson's and Jones' explanation. They show in addition that this single genetic factor is responsible for the sterility of this variety of rice-popcorn toward foreign pollen."

DEVELOPMENT AND ITS GENETIC CONTROL

GROWTH IN MICE

In the last Year Book, studies on growth of mice, conducted by MacDowell, are described. Progress has been made by MacDowell during the year in the isolation of the genetic determiners of growth from the numerous variables due to limiting factors outside of the animal. Innate growth-activators that operate by cycles have constituted a favorite theory of certain biologists. Most studies on the alteration of growth have been concerned with elements in the food, vitamins or hormones from endocrine glands; but the limiting effect of quantity of food seems to have been little studied. Last year's report indicated that by reducing the number of mice to be nursed in the litter to 4 the rate of growth of nurslings was increased. Despite this increase in milk available for each mouse a decline, or break, in the rate of growth appeared at the end of the first week, at a time when it occurs in unreduced litters according to Gates and Davenport. Saller has concluded that this break is surely due to innate causes. But MacDowell finds to the contrary. He reports—

"Each litter in a series of 15 was reduced to 4 young after the first feeding, to 2 after 5 days, and to 1 after 9 days. The conditions maintained and the technique of weighing and handling were such that each of the curves for individual mice is smoother than many curves based on averages. In every case the seventh day, as well as the three following days, were passed without a decline in the rate. The averages, as long as 4 young were nursed together, are identical with those obtained last year for litters also reduced to 4 at birth. But from the day of the reduction to two the new averages start to shoot up considerably faster. From this it may be concluded that under normal conditions the decline in the daily increment of growth found before the eleventh day after birth depends upon the mother; the available milk is the limiting factor, and the innate limit to growth rate is never approached in a normal sized litter.

"When these averages are plotted on a logarithmic field as a continuation of the straight line of prenatal growth reported last year, the first 11 points form a straight line. This demonstrates that, when sufficient food is available, the process of growth for 10 days before birth and 10 days after birth is fundamentally the same; the same law applies to both periods as both sets of averages give parabolic curves. The only difference between the specific formulæ for the two series consists in a slight reduction in one of the constants. This difference results from the altered life conditions after

birth, among which the constant loss of energy in the form of heat from the body surface and in the form of respiratory activity seem especially important. We conclude that with comparable conditions for the intake of nutrition and for the conserving of energy, a single specific formula would describe the growth of the mouse from the time of the primitive streak to the time it begins to leave the nest. Finding that the guinea-pig, on account of its long-delayed birth, actually presents this situation had led us to suspect that, as far as innate limitations are concerned, prenatal and early postnatal growth of the mouse are fundamentally the same."

Even the sudden reduction in growth at 11 days may involve the factor of food limitation, for at this time the young become more active and the mother's weight begins to fall. If fresh foster mothers are provided the break may be postponed. Also, as the young become adjusted to solid food their growth proceeds again at a rapid rate. When a nursling over 11 days old is rotated among a series of foster nurses, each nurse gives a characteristic change in weight each time it is on duty.

It is concluded that the 11-day break may be a consequence of a diminution of the mother's milk supply, just as the activity of the young begins to increase. "The hunger thus occasioned is the stimulus that leads to the replacement of the habit of turning the head up to nurse by the new habit of turning the head down to eat. This is the natural mechanism of weaning." To see if the break at 11 days can be prevented MacDowell plans to use (1) a succession of foster mothers at the height of their milk production and (2) rats as foster mothers.

SEX STUDIES

THE ESSENTIAL DIFFERENCE BETWEEN THE SEXES

Sex is one of the most wide-spread of vital phenomena. There is reason for concluding that when the essential difference (or differences) between the sexes shall have been found we shall have made a most important step in understanding an essential difference between living and non-living matter.

The work on the differences between the sexes that Miss Satin has been carrying on in collaboration with Blakeslee has made an important advance. They report that—

Her study of the quantitative differences in respect to sugars between extracts of male and female bread molds has been extended. The evidence is now sufficient to justify the general conclusion that in these forms females possess, on the average, a higher content of sugars than males. Comparative tests were made with 24 (+) and (—) *Mucor* races (included in 10 species and 8 genera) to determine the possibility of a given carbohydrate being present in one sex and not in the other. No such qualitative differences between the sexes were discovered. Trehalase, maltase and emulsin were present in all the tested species; amylase and glycogenase in all except one. Lactase was found in races of 4 species and sucrase and inulase in races of 2 species only. Among the species tested, *Cunninghamella* appeared to contain the greatest numbers of carbohydrases, species of the genus *Mucor* and *Parasitella* contained the fewest. In addition to glucose used as control, the relative value for *Mucor* development of 10 carbohydrates and

their derivatives, including di- and poly-saccharides, glucosides and a carbohydrate alcohol, can be shown approximately by the following order: Trehalose, maltose, salicin, amygdalin, starch, glycogen, mannitol, lactose, sucrose and inulin. Amygdalin, however, yields hydrocyanic acid and ultimately kills the fungus."

This research that was subsidized during two years by the Sex Research Committee of the National Research Council has been interrupted by the cessation of that support.

SEX RATIOS

Both common observation and the chromosome theory of sex lead us to regard the 50:50 ratio as normal, and to seek for special explanations of any considerable deviation from it in any species at any age of life. At this Department studies have been made on mice where various authors have suggested a variation in sex ratio dependent on age of mother and other special extraneous conditions, and on *Sciara* and *Cladocera* where the species are provided with special mechanisms regulating the sex ratio.

PRIMARY SEX RATIO IN THE MOUSE

Since 1925, when MacDowell reported the first direct data for a mammal on the sex ratio at conception, he has accumulated about three times as many cases which, according to the counts of the corresponding corpora lutea, have not been subjected to any prenatal loss, and consequently reveal the primary sex ratio. Our total includes 2,464 mice, giving 50.1 per cent males as the primary sex ratio. This agrees fully with our original finding and is very close to the proportion MacDowell finds for the secondary or birth ratio, when litters that have suffered prenatal loss are included. This last agreement bears out his conclusion, reached from various other data, that sex is not a factor in prenatal mortality in the mouse.

SEX RATIOS IN THE GENUS *SCIARA*

The remarkable sex ratios revealed by the fly, *Sciara*, have been the subject of further study by Metz, who reports as follows:

"In previous reports it has been noted that some species of *Sciara* give 'bisexual' and others 'unisexual' progenies, i. e., in the former type pair matings regularly give offspring of both sexes, while in the latter they give offspring exclusively, or almost exclusively, of either one sex or the other. One of the secondary objects of the field work this year has been to learn whether one of the types predominates and may be said to be characteristic of the genus or whether they are both common. Two of the newly found species have not been studied sufficiently to warrant a report on them but the other 6 are all of the 'unisexual producing' type. These make a total of at least 9 species of this type, as compared with not more than 3 of the other type thus far studied."

Some time was spent by Metz collecting *Sciara* in California with the purpose of learning whether within a species the type of behavior, as regards sex ratios, is constant in different regions. Metz reports on two common and widely distributed species, *S. coprophila* and *S. impatiens*

which were studied for this purpose. Both of these had been collected by him on the Atlantic coast and both uniformly gave "unisexual progenies." In California tests were made of 17 wild females of *S. coprophila*, from two localities, and 40 wild females of *S. impatiens*, from four localities. All of these gave "unisexual" progenies except one female of *S. impatiens*. The latter gave rise to the "bisexual" line of this species considered below. From the evidence at hand, it is concluded that it seems probable that this characteristic in the latter is due to a mutant gene, and that the strain does not represent a persistent wild race.

SOIARA IMPATIENS

On the behavior of this species Metz reports as follows:

"Experiments with this species have confirmed the earlier findings (last year's report) on *S. coprophila*, in showing that the female is responsible for the sex ratios. The evidence was obtained in two ways: (1) In the regular 'unisexual' stock by mating single males individually to several females and observing that one female may give only daughters and another only sons by the same male. (2) By using the 'bisexual' strain secured in California. Experiments with the latter are incomplete, but the records thus far obtained indicate that when crosses are made between the two strains the sex ratio is that characteristic of the strain from which the mother came.

"The 'bisexual' strain of *S. impatiens* promises to be of great value in analysing the processes responsible for the sex ratios and for sex determination in these flies. For this reason it is being studied intensively and is being used in conjunction with the ordinary 'unisexual' lines. Pending the completion of present experiments the following observations are reported as a provisional indication of the genetic background with which we are dealing.

"The original female of this line gave 20 daughters and 32 sons. Seven pair matings from these gave bisexual progenies and 3 gave progenies mostly of one sex. In the next generation many matings gave 'unisexual' progenies. This would seem to indicate that the line was not 'pure' for the 'bisexual' characteristic and that the latter is due to a segregating genetic factor.

"In crosses between females from the 'unisexual' line and males from the 'bisexual' line all (18) matings gave unisexual progenies. The second generation (F_2) from this cross has not yet hatched. F_1 females backcrossed to 'unisexual' males gave unisexual progenies and F_1 males backcrossed to bisexual females gave bisexual progenies.

"In the reciprocal cross, of 'bisexual stock' females by 'unisexual stock' males, many of the matings gave bisexual progenies. In those which did not, the females were presumably not 'pure' for the bisexual characteristic.

"The evidence taken together is such as would be expected if the 'bisexual' characteristic were due to a mutant gene which interferes with the normal sex determining processes. Since sex mosaics are very frequent in this strain it is postulated that chromosome distribution is affected. Experiments are under way which, together with cytological observations, are expected to furnish an explanation of these phenomena."

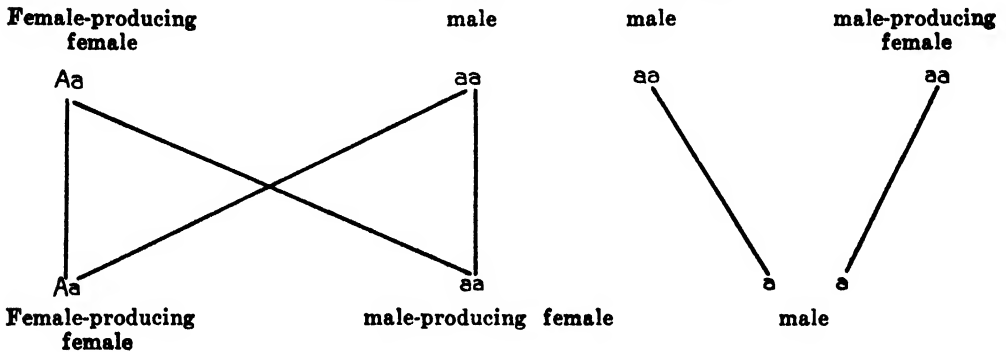
SEX-RATIO DETERMINATION

Dr. Metz finds, as previously noted, that—

"In the species giving 'unisexual progenies' the sex ratio is dependent on the mother. Earlier records have shown that ordinarily, in a female progeny, both types of females are found (female-producers and male-producers). This suggests that sex-ratio determination is a mendelian character dependent on a pair of segregating genes or chromosomes. If so, and segregation is at random, the two types of females ought to be regularly produced in equal numbers.

"To check this 381 females from 28 families have been tested individually. Part of the tests involve *S. impatiens* and part *S. coprophila*. In all cases both types of females were found in approximately equal numbers, save one series involving only three matings. The totals are as follows: *S. impatiens*, 60 female-producers: 60 male-producers; *S. coprophila*, 134 female-producers: 127 male-producers.

"On the basis of the evidence thus far obtained it is postulated that sex-ratio-production is inherited according to the following scheme:



On this view "exceptional" females in male progenies should all be male-producers and half of the "exceptional" males, if viable and fertile, should give different genetic results from ordinary males. These features are being tested.

SEX RATIOS IN CLADOCERA

Studies on control of sex ratios in *Moina macrocopa* are nearing conclusion. These studies, in collaboration with Dr. L. A. Brown, have now been in progress for eight years. Some experimental work has been done during all times of the year, but the work has been much accelerated by intensive work during summers—when Brown was able to collaborate. In all there have been nearly 2,900 separate experiments, involving approximately 75,000 mothers and a million sexed young. This study has covered most of the apparently feasible points of attack, although a few points still require further elucidation.

RELATION BETWEEN RETARDATION AND MALE PRODUCTION

Series of our experiments in which time of release of the young was carefully obtained show, as previously reported, a direct relation between the degree of retardation of release of the young and the percentage of male young produced. A recent survey of these data indicates that the two phenomena progress *pari passu*, and this is true regardless of the treat-

ments employed, whether crowding (*i. e.*, the accumulation of the animals' excretory products) or some other biological or chemical treatment. Table 3 presents the data for one group consisting of four series of experiments and shows the amount of retardation (produced by crowding to various degrees) and the percentage of male young produced.

MECHANISM OF SEX CONTROL IN CLADOCERA

Cytological studies were made by Dr. Ezra Allen on our material of *Moina macrocopa*. His findings, partly new and partly confirmatory of other work, are—

"That the parthenogenetic egg in *Moina* is diploid, whether it is to produce a female or a male young; that in the first and only maturation division of the parthenogenetic egg the spindle begins to appear and the chromosomes assume a definitive appearance shortly (about $\frac{1}{2}$ hour or less) before the eggs are laid—fully 3 or more hours after the critical period."

Further, Allen found that all the parthenogenetic eggs of which he secured satisfactory chromosome counts, including some which presumably would have developed into males, contained the same number of chromosomes—22. But Allen's counts were few and he considers it entirely possible that there are some (male-producing ?) eggs with fewer chromosomes.

Balked though we have so far been in ascertaining the nature of the sex-determining mechanism in Cladoceras, Banta and Brown hold that it is not improbable that it is like that worked out by Morgan (1915) for phylloxerans and aphids, in which the males are diploid but lack half of the X-chromosomes. The male so produced gives only male-determining sperm, inasmuch as the sperm containing no X-chromosome degenerates. Certainly Cladocera, like the phylloxerans and aphids, have diploid parthenogenesis, and the males produced parthenogenetically are diploid. The fertilized egg produces only female young. Whatever the mechanism of sex-determination, our experimental studies have demonstrated that sex in these organisms is subject to environmental control.

SEX DIFFERENTIALS IN PIGEONS

A SEX DIFFERENCE IN PITUITARY SIZE AND INTESTINAL LENGTH

In a short publication on this subject Riddle, working with the assistance of Miss Flemion, has reached the results that are summarized as follows:

"Adequate data from adult ring doves show that the females of these forms have longer intestines (5 to 10 per cent) than the males. The presence of round worms (*Ascaridia*) is here associated with a slightly increased length of intestine in both sexes.

"Some new data for pituitary size in pigeons of both sexes agree with earlier data of McCarrison in indicating that in these animals the females have larger pituitary glands.

"The few items of adequate data now available for man, rat and bird lead to the conclusion that there is a sex difference in both pituitary size and intestinal length. And that this difference involves a larger pituitary (particularly anterior lobe) and a longer intestine in the female. These results are probably of importance to the solution of a number of biological and clinical problems."

TABLE 3—*Experimental data illustrating results of the degree of crowding upon amount of retardation of the production of young and percentage of male young produced*

No. mothers	2-4			7-9			12-17			23-29			30-36		
	Total young sexed	% ♂	Retar- dation in hours	Total young sexed	% ♂	Retar- dation in hours	Total young sexed	% ♂	Retar- dation in hours	Total young sexed	% ♂	Retar- dation in hours	Total young sexed	% ♂	Retar- dation in hours
8	242	10.7	0	721	26.3	5.6	868	23.0	7.5	129	78.3	7	483	81.0	12.6
3	106	0	0	325	27.1	3.7	226	79.1	7.5	908	65.6	11.4			
4	243	0	0	475	22.3	6.6	718	48.5	8.2						
3	61	9.8	0	105	24.7	6.5	256	28.5	—						
18	652	4.9	0	1,626	25.3	5.6	2,068	35.8	7.7	1,037	68.1	10.5	483	80.9	12.6

SEX AND SEASONAL DIFFERENCES IN WEIGHT OF LIVER AND SPLEEN

On this subject Riddle has published results which are summarized as follows:

"(1) Weights of liver and spleen obtained at all months of the year on 499 male and 444 female, healthy, adult ring doves demonstrate that a true sex difference exists. Though the male body weight is slightly larger, the male livers and spleens are smaller, 9.4 per cent and 23.5 per cent, respectively. (2) A true seasonal increase in size of liver and spleen occurs in spring and summer in both sexes (10.4 per cent and 12.0 per cent in males; 6.1 per cent and 4.3 per cent in females). (3) These changes in spleen and liver are positively correlated with size changes in testis and ovary; and negatively correlated with size changes in the thyroids of these animals."

PHYSIOLOGY OF SEXUAL REPRODUCTION AND DEVELOPMENT
MICE

NUMBER OF OVA IN ONE OVULATION

In studying factors influencing the number of ova reaching maturity at one ovulation, MacDowell reported in 1926 that the previous reproductive history of a mother was more closely correlated with the number of ova than the age of the mother, and in 1927 he described an increase in the mother's own weight accompanying pregnancy. That there is a relationship between these two findings is shown by a study of the correlation between the weights of the mothers (330) at the time of conception and the number of ova matured at this time. Beginning with mothers of 14 grams and proceeding by one gram classes to 24 grams the average number of corpora lutea rises gradually from 6.5 to 12.8. Above 24 grams added weight, which is largely due to fat, does not contribute to further increase in the number of corpora lutea. The mechanism which accounts for this correlation has been made clear by Smith and Engle who demonstrated the direct effect of the transplanted anterior lobe of the hypophysis on the number of ova. A positive correlation between body weight and size of the hypophysis may readily be taken for granted.

PRENATAL MORTALITY

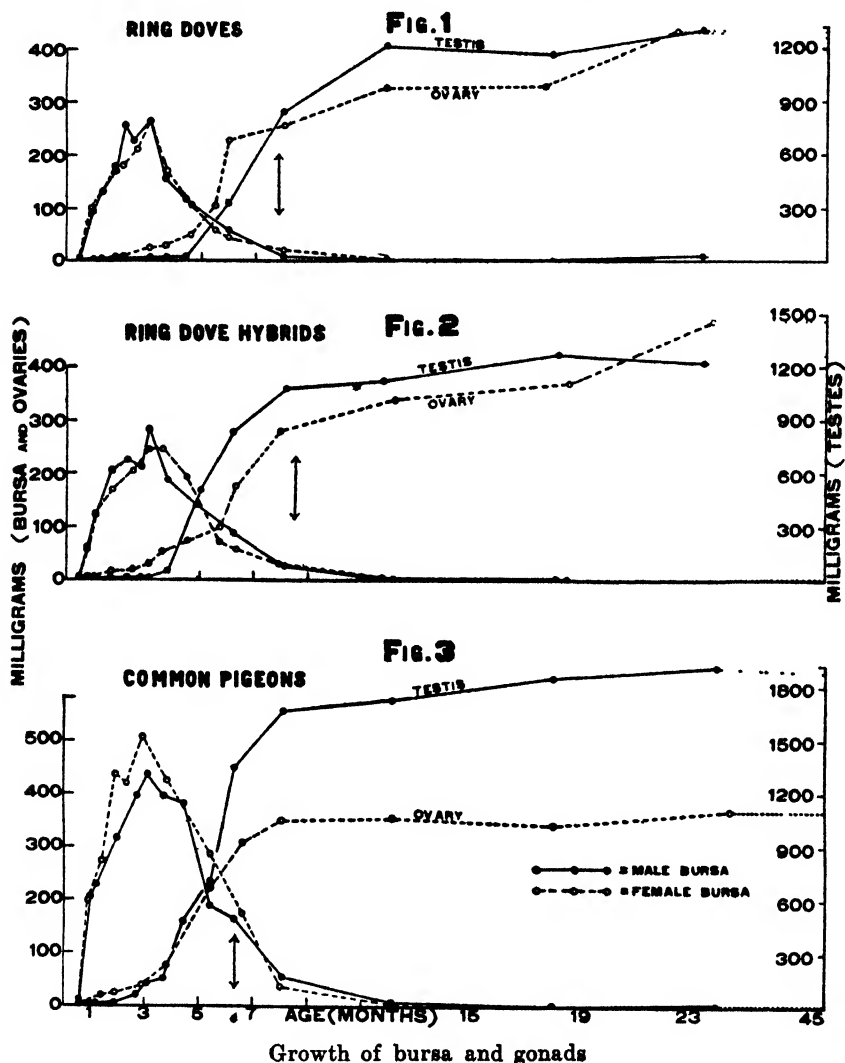
New studies on the frequency of mortality at different stages of gestation have been focused on the earliest period of implantation. At 5 days after conception the number of implants can be easily determined and the corpora lutea are sufficiently developed to be counted if the blood does not escape from them. Of 80 litters on the fifth day of pregnancy, 54 per cent were perfect. Eight per cent of the total number of corpora lutea were not represented by implants. This result, compared with 30 litters of the seventh to ninth day of gestation, of which 30 per cent were perfect, and 16 per cent of the corpora lutea were not represented, indicates a marked rise in mortality very near the seventh day, at the time the primitive streak begins to appear.

PIGEONS

MECHANISMS THAT REGULATE AGE AT WHICH SEXUAL MATURITY OCCURS

In pigeons, as in organisms in general, sexual maturity is heralded by a great increase in the size of the germ-glands. Riddle has sought for the internal factors that first repress and then promote the growth of the gonads.

It appears that the bursa Fabricii and the thymus exert a retarding action on the growth of the germ glands. The evidence is of two kinds. First, the fact that the germ glands change very little in weight during the period of rapid growth of the bursa and thymus, added to the fact that the germ-glands begin a much more rapid growth precisely coincident with beginning atrophy in the bursa and thymus. The relation between growth of bursa and gonads is shown in figures 1 to 3. Second, in general, in these particular



individuals that attain sexual maturity at advanced ages, the bursa does not begin to atrophy until after the normal age of 3 months. This relation holds not only for individual doves but also for various species that attain sexual maturity at greatly varying ages. The bursa may be regarded as a second, cloacal, thymus.

In another investigation Riddle, assisted by Miss Florence Flemion, has found that a substance extractable from the anterior lobe of the pituitary body exercises an accelerating influence on the growth of the germ glands of

young, and particularly male, birds. One such extract injected into 11 young males apparently gave a positive result in every case—6 to 12 daily injections were administered to these males. It appears that all of the treated males had testes 2 to 15 times heavier than the average of the controls. Indeed, all except 3 of the treated birds had testes that were heavier than the heaviest found among the several birds serving as controls. The exceptions were found among the three birds that were treated during the shortest period—only 6 days.

This effect of pituitary extract in promoting gonadal growth is the more striking when compared with the slighter effect of transplanting glands of mature birds, in which experiment 509 transplants were used.

MATERNAL INFLUENCE ON GROWTH IN THE SEX GLANDS OF EMBRYOS

In our report of last year were brought together the facts which indicate that the sex glands of the mammalian (and human) fetus are probably modified by the maternal female hormone which passes through the placenta and enters the circulation of the embryo. Riddle is now able to present data that make it probable that the sex glands of the bird embryo are similarly affected by this same hormone which Fellner has found to be present in the egg yolks. He reports:

"The adult testes are 3 to 5 times larger than the adult (resting) ovary, but the testes of the newly hatched dove embryo are only half the size of the ovary at hatching. These facts are made clear by the data of Table 4.

TABLE 4—Size differences in testes and ovaries in the adult and at hatching

Kind of bird	Sex	Weight of—		
		Adult gonad	Body weight at hatching	Gonad at hatching
		mgms.	grams	mgms.
Ring doves.....	Male	1300	(5.60)	0.61
	Female	432	(5.13)	1.30
Ring hybrids	Male	1420	(5.61)	0.60
	Female	499	(5.31)	1.24
Common pigeons	Male	1913	(9.92)	1.51
	Female	367	(9.88)	2.46

"These marked modifications of the embryonic growth of organs, probably as the result of the regular though essentially accidental inclusion of a maternal hormone within the egg, are of interest in the theory of development—of heredity. The conditions actually found are currently considered normal, though they are quite as abnormal as those effected by the experimentalist. In development, the word 'normal' can merely mean 'the usual.'

"Obviously these results, in addition to their bearings on sex and development, contribute a point of importance to the theory of *growth*."

THE EXTIRPATION OF THE BURSA FABRICII IN YOUNG BIRDS

This obviously glandular organ of unknown function is found exclusively in birds and is very large in young birds. Three years ago this organ was

removed from 66 young doves by Riddle and Tange; and the operated birds allowed to live and reproduce during 2 years. Autopsies made at the end of the period have led Riddle to the conclusion that bursectomy alone does not alter growth-rate nor age at maturity. Thus the bursa alone seems to have no function that is not duplicated by the thymus. The removal of the bursa may have been responsible for an increase noted in left oviducts in males and right ovaries and ducts in females.

**BASAL METABOLISM IN RELATION TO SEX, HYBRIDITY AND ENDOCRINE RACES
IN PIGEONS**

The extensive program of study of these subjects in which Riddle is collaborating with Director Benedict of the Nutrition Laboratory has been advanced somewhat slowly, owing to the inherent difficulties of the problem. Our main purposes require a very great number of measurements of truly basal values. Before even one such value can be definitely recognized as such it has been necessary to test the influence of many possible factors, and each of these has required many measurements—in a previously untried species. The pigeon has proved to be an animal with a highly labile metabolism, and our first two years of study have been very largely devoted to the establishment of the precise conditions, technique and apparatus necessary to give us truly comparable and basal values of heat production.

Riddle and Benedict have found that conditions other than mere fasting during the 24 hours preceding the metabolism measurement have a marked influence on the values obtained. It was found that an enforced 24-hour fasting period must be started with food in the bird's crop (5 grams in ring doves; 10 grams in common pigeons) if consistent values were to be obtained; also that sometimes a bird was starting the fasting period with no food whatever in the crop, and that such cases require "stuffing" or feeding by hand. In addition, it was learned that the temperature at which the bird was kept during this 24-hour period markedly influences the metabolic rate of the bird at the end of the period. The higher values of the calories after maintenance at 30° are probably to be interpreted as a result of a food-conserving action of the higher temperature. Riddle reports further, as follows:

"Of much interest to our sex studies is a result obtained from a study of the effects of previous inactivity, or close confinement, on the metabolism of ring doves. A year ago we carried out one such study on 15 doves—7 males and 8 females. These birds were kept from 5 weeks to 3 months in cages having a capacity of only about 1 cubic foot; no flight was possible. At the end of this period they were found to have an average metabolism of 3,195 calories (per 4 hours per 150 gram bird). They were then placed in their usual, very much larger, cages and after 5 weeks their rate of heat production was again measured. At this time the average value for the 15 birds was 3,519 calories—an increase of 11 per cent. Inactivity, or close confinement, therefore, markedly affects the basal metabolism of these animals.

"The particular fact in these results which is of highest interest to our studies, however, remains to be stated. The data obtained from this test indicate that the close confinement did not equally affect the two sexes. The males, so to speak, were hit hardest; they lost 14.9 per cent of their normal

basal metabolism; the females lost only 7.3 per cent. These results are based on 36 satisfactory measurements. The tests are now being repeated on 32 individuals.

SOLIDS OF SKELETON AND FEATHERS IN PIGEONS OF VARIOUS AGES AND RACES

Data on this subject are being collected by Riddle with the assistance of Miss Comunale, with the aim of determining the extent to which differences in basal metabolism in our birds are dependent upon the presence of varying amounts of non-metabolizing or inert tissue. These data should prove of much value in the final calculations of the heat production values obtained from our collaborative study with Benedict.

CLADOCERA

THE HATCHING OF THE SEXUAL EGGS OF CLADOCERA

Sexual eggs of Cladocera are adapted to a considerable period of inactivity, and it is difficult to hatch them on demand. Banta had formerly been able to get only about 14 per cent (out of 5,440 eggs) to hatch. This year, through the courtesy of the Boyce Thompson Institute, at Yonkers, it has been possible to subject various lots of eggs to different constant temperatures, 5°, 10° and 20° C. for different periods, 1 month, 2.5 months and 4 months. These experiments, together with additional experiments at Cold Spring Harbor, establish the following rules for increasing hatches: (1) the dry storage of eggs greatly shortens the latent period; (2) if hatching is delayed until 3 or 4 weeks after deposition, wet storage is better than dry; (3) placing in the standard culture medium accelerates hatching more than in clean pond water; (4) frequent renewal of culture water increases the hatching rate. By following these rules the hatching rate of sexual eggs is now nearly 50 per cent, and over 900 sexually produced young have been obtained. The success both in securing fertilized eggs in large numbers and in hatching them is largely due to the perseverance and technical skill of Miss Thelma Wood.

GENETICS OF SPECIAL TRAITS

HEREDITARY VS. NON-HEREDITARY VARIATIONS IN CLADOCERA

Most taxonomic work on Cladocera has been based on collections made in the wild and without regard to the genetic nature of the differences upon which new "species" are erected. In the genus *Diaphanosoma*, two American species are recorded, of which one, *D. brachyurum*, is found on the weedy margins of lakes, the other, *D. leuchtenbergianum*, is found in the open water. Birge, a leading American taxonomist of the group, suspected that the latter species is merely a limnetic variety of the former. Banta has found both forms in Florida and has bred them in bottles for over 100 parthenogenetic generations. They have retained the differential characters they had "in Nature." They may be accepted as genetically distinct.

RACE DIFFERENCES IN METABOLISM OF PIGEONS

The work of establishing special "endocrine races" among our 40 races of pigeons has been actively continued by Riddle. Data have been accumulated on thyroid size, in crosses between "small thyroid" and "large

thyroid" races; and on intestinal length of hybrids between races with long and those with short intestine.

MICE

During the year under review new mutations in our stock of mice have been studied. Some of these are of a simple sort and some are complex, and the latter are quite as interesting as the former, inasmuch as the number of characters in man that are irregular in their inheritance is very great.

SHAKER GENE

An autosomal gene in the mouse, which will be called *shaker* with the symbol $s^h s^h$ has been discovered by MacDowell. The mouse rarely waltzes but its head characteristically undergoes vertical movements. Such mice sleep a great deal and become deaf when adult. A tetanic condition follows lifting by the tail. Inbred shakers give all shaker young. Heterozygous parents have given 85 normals to 35 shakers; back crosses have given 62 normals to 59 shakers. Professor W. H. Gates of the University of Louisiana finds the shaker and waltzing genes distinct.

EYE DEFECTS

The inherited eye defect reported by Little and Bagg in the Year Book for 1922, when inbred, gave 20 per cent normals. Since that time this strain has been inbred and selected for the abnormality for 16 generations without decreasing the proportion of normals (706 young from current matings give 23.5 per cent normals), and without increasing the proportion of mice with both eyes affected, 7 per cent against 10.4 per cent reported by Little and Bagg. This indicates that the variation in the expression of this defect is not dependent upon the segregation of modifying factors. In contrast to this strain, a slightly different eye defect has been found which appears to be dependent upon several genes; the selection of abnormal parents has been accompanied (1) by a steady decline in the normals from 90 per cent to 20 per cent during 11 generations involving over 2,000 animals, and (2) by a steady increase in the number of mice with both eyes affected, from 0 per cent to 38 per cent. Defectives bred together are giving 15 per cent more defective young than their normal sibs bred together, so there is still some genetic difference between defectives and normals, and selection may be expected to make further progress. These defectives bred to the strain of Little and Bagg, as well as to several unrelated normal strains, give only normal young in the first generation. However, one apparently normal strain was found to carry enough of the same genes to permit the defect to appear in the first generation.

CIRCLING

This new inherited behavior trait is differentiated from Japanese waltzing, in that the mice are able to run long distances in straight lines, the aggravated head movements are absent, they are not deaf, the character appears only in the adult and the genetic basis is complicated. Through the cooperation of Dr. F. W. Flinn, of the Department of Industrial Hygiene of the College of Physicians and Surgeons of Columbia University, who is

engaged on metal poisoning, we find that the trait is not due to metal poisoning, nor is it due to a peculiarly sensitive nervous organization that leads to circling as a habit complex, instigated by cramped quarters. Through the cooperation of Dr. W. V. Cone, neurologist at the Presbyterian Hospital, we have learned of the histological conditions in the ear of these circling mice. He reports only one case of infection in the middle ear. Hence, the circling is not due to infection. No obvious neurological abnormalities were detected. Whence it appears that the structural basis of circling is probably very inconspicuous.

LYMPHATIC LEUKÆMIA

This is a disease involving hypertrophy of the reticulo-endothelial system (liver, spleen, lymph nodes, etc.), with characteristic blood picture about which not much is known beyond its inevitable fatality in man. This occurs in one of our inbred strains in a way to demonstrate it has a genetic basis. Genetic study must wait on a better knowledge of its pathology. We are especially gratified to have secured the cooperation of Doctors Pappenheimer and Richter of the Department of Pathology of the College of Physicians and Surgeons, who are taking responsibility for the pathological side, while Dr. MacDowell will study the genetics. Large numbers of this strain are being reared and it is hoped through blood smears to make an early diagnosis.

THE THOROUGHBRED HORSE

In the development of this research, to which Mr. Walter J. Salmon continues his generous support, Laughlin has worked out a set of Standard Tables for quality of performance for colts, fillies and geldings for each distance run between 2 and 18 furlongs at each weight carried on back between 85 and 140 pounds, and for each quarter year of age from 2 to 5.75 years. Thus a standard speed has been established for each complex of sex, age, distance and weight carried. This is a necessary step in computing the racing capacity of individual horses. In determining the biological handicap—that is, the racing capacity—of a given horse, the mean quality of performance of the best 25 per cent of his races run is computed. The reason for selecting the top values only is to eliminate, so far as possible, the influence of other factors, principally condition of horse, condition of track, and quality of riding. The top 25 per cent of the values seems to represent, much better than all races, the real capacity of the horse in terms of sex, age, distance run and weight carried, which factors are duly intercompensated in the computation of quality of performance.

In order to preserve the terminology with which horsemen are familiar, and at the same time to give racing capacity an exact, quantitative expression in place of general judgment of the professional handicapper, who estimates "this to be a 110-pound horse and that a 120-pound horse," a series of Biological Handicaps has been computed on the basis of the Standard Tables just described. Biological Handicap (B.H.) is expressed in "pounds" (as carried on the horse's back) while mean Quality of Performance (Q.P.) is the average of the ratios of performance for all of the particular horse's top races. Each of these ratios is the Standard Mean Seconds per Furlong

for horses of the particular sex and age, carrying the particular weight and running the particular distance, *divided* by the Mean Seconds per Furlong actually made by the particular horse in the particular race. The relation between these two measures is expressed in the empirical equation $B.H. = 716 \overline{Q.P.} - 585$. Since mean $\overline{Q.P.}$ is a straight line function of B.H. it is for many purposes immaterial whether we use $\overline{Q.P.}$ or B.H. as a measure of a horse's racing capacity.

HUMAN GENETICS

RACE CROSSING IN JAMAICA

Field work, collecting materials for the study of negroes and whites in Jamaica and crosses between them, was completed by Steggerda in December 1927. About 8,000 sheets of data were deposited with the Department. About six months were required for work on the data, and in May the results were accepted for publication by the Institution.

The completed work comprises (1) an introduction, dealing with methods employed in the research; (2) anthropometric results; (3) physical observations, physiology and correlations; (4) results of psychological tests; (5) developmental studies; (6) family studies and (7) general discussion. A body of conclusions concerning comparative proportions of Blacks and Whites was gained; some of which are new. The division of the appendages, elbow and knee joints lies in the negro proximal to that of the White. The external ear (pinna) is rounder in the negro; the teeth of the negro show the less decay than the teeth of whites, up to 16 years of age, but more at a later age. The papillary patterns of the negroes, as compared with Whites, have nearly 50 per cent more whorls. Radial loops are relatively much rarer than in Whites of the Cayman Islands—which run above the white average. The Blacks are relatively glabrous.

The blood groups were ascertained by Laurence H. Snyder, who finds that the Blacks in the new environment of Jamaica still carry proof of their African relationship. F. G. Benedict, of the Nutrition Laboratory, finds from the basal metabolism records that the natives of the tropics have a basal metabolism not essentially unlike that of northern Whites. There is a high correlation between skin color and nose index.

In musical capacity the adult Blacks surpass adult Whites in rhythm and pitch; and also intensity and time. The West India band scored exceptionally high in time and rhythm. In copying and improving drawings the Whites were the superior; and the same result was obtained from six other tests but in the repetition of 7 figures the Browns are definitely superior to the other groups at all ages. In the Army Alpha tests the Whites were clearly best in common sense, in selecting synonyms and antonyms, in restoring piced sentences and in general information. The other differences are not statistically significant, but the Browns stand lowest in 5 out of 8 tests.

The study of development shows that the long-legged condition of the Blacks is not due to the persistence in the adult of the 12-year old condition found in Whites; but is present probably from birth on. At birth Black babies weigh less than White ones; and the head of the newborn Negro is smaller than that of the White.

Variability is greater in the hybrid Brown than in the parent stocks in just those traits in which the races differ in simple genetic fashion. The 5 to 10 generations that separate the Jamaican negro from Africa have not sufficed to obscure his general resemblance to the present West Coast African. But there are some differences, probably due to new mutations.

The evidence is convincing of fundamental differences between Negroes and Whites in the different mental capacities. While, on the average, the Browns are generally intermediate in mental capacities between Whites and Blacks and although some of the Browns are equal to the best of the Whites in one or more traits, still among the Browns there is an excessive percentage who seem less able even than the Blacks to utilize their native endowment.

In preparation for the foregoing work, Steggerda had received detailed typewritten instructions as to anthropometric (as well as psychometric) methods. The anthropometric instructions were later published as a booklet by the Eugenics Research Association, and there has been a fair demand for it.

MUSCULAR DISCRIMINATION OF FORM

In continuation of the form discrimination test, Mr. Ralph K. White worked on solid objects of a regular character and those of a slightly deformed character as a test of ability to discriminate form with the muscular sense of thumb and forefingers. This work was done under a grant made by the Eugenics Research Association. It appears that there is great difference between persons in their ability to make this discrimination.

HEREDITY OF GOITER

The study of the data of goiter in Maryland families, undertaken in collaboration with the Playground Athletic League of Maryland, has been postponed to make way for the Jamaican studies and to secure data concerning iodine distribution in the waters of Maryland. Meanwhile new methods of analysis of the data have been applied.

HEREDITY OF ATHLETES

The tabulation of the data gathered by Richard H. Post for this study, in cooperation with the Carnegie Foundation for the Advancement of Teaching, has been for the most part in the hands of Miss Mary F. Toof, owing to the resignation of Mr. Post. Scores of correlations and contingency coefficients have been computed and the descriptions of families has been typed. It is believed that the work can be completed by the autumn of 1928.

HEREDITY OF OTOSCLEROSIS

The committee on otosclerosis of the American Otological Society has requested this Department to conduct a research in heredity of otosclerosis and has apportioned a sum of money for the purpose. The services of Dr. Bess Lloyd Milles were secured on part time, beginning April first, and about 20 families have been partially studied. The work will be continued during the coming year.

HEREDITY OF MENTAL TRAITS

Banker has been engaged during the year in further elaboration of the utilization of teacher's marks as measures of intelligence. The Student's Ability Index, SAI (described in last year's report), has been compared with the Intelligence Quotient (IQ), derived from standard group tests and a high degree of correlation between them has been found. With respect to any specific individual—

"Neither the IQ from a group test, as commonly administered, nor the SAI derived from the school record of the student, can be predicated as an absolutely accurate measure of the individual's actual ability, much less of his intelligence. On the average, however, the SAI's of a large group of students in a well-conducted school should be substantially the same as the average IQ's obtained from a group test of the same students, and will have about the same distribution. It seems possible, therefore, to use SAI with reasonable assurance in such cases where a group test would be serviceable but impracticable to administer.

"The first half of the year was occupied in completing these studies which required the computation of thousands of SAI's and the compilation of scores of distribution tables.

"The latter half of the year has been given to the computation of the SAI's of genealogically related individuals, with a view of determining the distribution of the qualities measured, of whatever sort, among the members of a family. This work is still in progress and it is too early to make any positive statements as to results. We feel, however, fairly safe in saying the present indications are that student ability as measured by this index shows approximately the same correlations as have been found in measurable physical characters. That is, between parents a positive correlation with a coefficient of about 0.2 to 0.3, and between parents and children a positive correlation with a coefficient as high as 0.5. Such definite correlations seem to be clear evidence that we are dealing with the measure of a complex of fundamental factors having genealogical relationships. Whether it may be possible to analyze such a complex into genetic factors is problematical."

GENETIC CONSTITUTION OF THE AMERICAN POPULATION

EUROPEAN RACIAL DESCENT OF PATENTEES IN RELATION TO NUMBER AND KINDS OF PATENTS ISSUED

In collaboration with the Committee on Immigration and Naturalization of the House of Representatives, Laughlin has continued work on the racial analysis of patentees who were issued patents by the United States during the first three months of 1927. Of these 10,440 patentees, first-hand returns were secured from 8,734. These returns gave, besides other data, place of birth and occupation of the patentee, and the racial descent of each of his four grandparents. Hollerith cards have been punched for the returns received and correlations are being worked out under the following classifications: Where born (foreign nations and states of the United States) 96 classes; occupation, 91 classes; racial descent, 47 classes; type of invention, 296 classes. .

There are two purposes of this study: one is to find the relation between racial constitution of the inventor and frequency and kind of inventions.

The second purpose is to find out to what extent, by a survey, the racial make-up of a given population group can be determined. A large proportion of the replies have a significance for this subject. The present study has shown that it is feasible to seek the analysis of ordinary American population groups on the basis of principal European racial descent of each of the four grandparents.

EUGENICAL ASPECTS OF DEPORTATION

This study, which Laughlin has continued for a number of years, has been completed and its results published. Among other objects, this work included an investigation of the foreign-born inmates of all state and federal custodial institutions for the socially inadequate classes. 74,170 foreign-born inmates were located in 684 institutions. These represent failures of the admission-examination of immigrants to detect persons liable to become public charges. The eugenical bearing of this condition is that, in so far as the social inadequacy of these persons is due primarily to heredity, (1) these inadequates affected unfavorably the quality of the American population to the extent to which they reproduced here before commitment; (2) some of their blood-kin, admitted as part of the same family group, are carriers of defective genes which may get into future American offspring; (3) if released into the American population during their procreative period these inadequates may further reproduce their defects here.

Both the expense of maintenance as public charges and the danger of reproduction, if discharged, call for the enforcement and extension of the deportation laws in the case of such aliens as become public charges primarily from hereditary defectiveness. The present study shows the necessity for adding to the individual standard and inspection a study of the near-kin and a family-stock standard, if immigration is to be used to improve the inborn quality of the American people.

MIGRATION WAVES IN AMERICAN HISTORY

Studies were continued by Laughlin on the relation between the character of the American institutions and migration during national development. A study was made of each of the six major racial problems in American history as follows: First, the effort of the white colonists along the Atlantic seaboard to prevent destruction by racial mixture with the American Indian; second, the conflict for racial and institutional supremacy between the British colonists on the one hand and the French, Dutch and Spanish on the other; third, the introduction of negro slaves; fourth, oriental migration; fifth, radical changes in racial and individual character of immigrants paralleling the rise of American industry during 1880-90; and sixth, the northward migration of colored races from the southern states, from the West Indies, and from Mexico since 1920. It is shown that each of these waves played an essential part in the development of the American race and institutions of today, and that each of these waves was critical in the sense that had the successful waves been stopped early, or had those waves which were stopped developed to their full possibilities, American racial and institutional conditions of today would have been vastly different.

EUGENICAL STUDIES ON THE POPULATION OF THE SOUTHERN APPALACHIANS

The field work on the Southern Appalachian mountaineers having been completed, Estabrook is preparing his final report. This report involves a consideration of the population from which that of the pioneer migrants to the mountains came. The migrants were predominantly English, Scotch and Irish, with some Germans and a few French Huguenots. The majority had come to America for freedom of religious worship and greater economic opportunity. In addition to these voluntary migrants were the convicts that England sent during a hundred years—criminals, paupers, debtors and dissolute women. They had been planted in the southern section of the colonies, from Pennsylvania southward, and it was from this area that the first migrants to the Southern Appalachians passed. No ship's manifests, or other lists of such persons sent by "free passage," have been found; so it is impossible to know what family lines in the United States in 1800 were from this defective group.

Certain it is that it was a selected population that faced the hardships of the migration to the mountains. Doubtless many were fugitives from slavery for debt and from the social organizations. The land to which they came was not good for agriculture and the more ambitious families passed further west. Those who remained were thus selected out as the least ambitious and successful. Estabrook continues—

"The present studies also show that the individuals with the higher intelligence scores and the better grade ratings in the mountain schools tend to leave the mountain areas, while those with lower ratings and less schooling tend to remain. A large number of factors have thus worked to sort out and move from the mountains the individuals with more energy, better ability and education. This extensive migration from the privileged, as well as the under-privileged, sections of the Southern Appalachians for the past one hundred years has taken away much of the better germ plasm. The present population of the Southern Appalachian mountains, therefore, is not similar biologically to that which entered the area.

"The population now in the more isolated sections has an average intelligence level lower than that found in the more privileged areas in the mountains.

"Studies of the occupation and birthplace of the individuals paying federal income tax have been made in several sections. These have included rural, semi-industrial and industrial centers—all in the mountain section of Kentucky. The number paying such income tax is very small in the rural areas. It is much greater in the industrial centers. This industrial development, arising from the mining of soft coal in Eastern Kentucky, started about twenty years ago. It was followed by a large immigration of outside population. The number of individuals for every thousand of this outside stock paying an income tax was much greater than the number of individuals of local stock, per thousand. Analysis of these data also points to the fact that the local stocks have been losing their most energetic individuals by these migrations during this past century; hence the general level of ability and activity of the purely local stocks is below the general average of the whole population.

"A study of poor relief in several counties in Eastern Kentucky indicates that there is a definite pauper class which has been a recipient of relief for

many years. This pauperism is found to be quite high in certain family groups.

"These studies indicate that the conditions now found in the Southern Appalachians are mainly the result of biological selection and do not ensue from the isolation and consequent under-privilege."

ADMINISTRATIVE RECORD

The combined libraries of the two sections of this Department comprise 12,570 bound books and numerous catalogued pamphlets. On June 30, 1928, the books in the archives of the Eugenics Record Office amounted to 1,870; field reports to about 7,600 sheets; special trait files, A & S, 30,112; Records of Family Traits, 11,222. We have received during the year about 1,285 sheets of various other schedules, 588 pages of original genealogical manuscript, 4,098 biographical press clippings and 488 pages of "Fitter Families" schedules. The index cards amount to 1,285,500. Some 26 collaborators sent in collections of Family Records from educational and other organizations.

GEOPHYSICAL LABORATORY ¹

ARTHUR L. DAY, DIRECTOR

STUDIES OF WEATHERING AND SEDIMENTATION

LABORATORY WORK *

After the formation of the earth crust, various processes began to be operative to modify it in different ways. These processes, known as metamorphic, may be of different character. Some of them are due to changes in temperature or pressure, or the two combined; others, and these are the ones chiefly under consideration at the moment, are due to the interaction of surface water or aqueous solutions with the individual rocks, for the most part in contact with the atmosphere. These processes comprise what is usually known as weathering and sedimentation in the broader sense, and consist of such chemical reactions as solution, hydration, oxidation, carbonation, etc. The interaction between the original rock and the aqueous solution results in most cases in the production of one or more new and different mineral species, which may be deposited *in situ* or transported some distance away before deposition takes place.

Weathering and sedimentation have been going on continuously through geologic time under varying conditions, which in many cases have produced complex results. However, these processes are governed strictly by physico-chemical laws and their general elucidation is therefore dependent on the accumulation of sufficient knowledge of the properties and behavior of the substances involved. The best example of the applicability of physico-chemical studies to the interpretation of such geological phenomena is Van't Hoff's classical work on the Stassfurt salt deposits.

Our knowledge of the stability and conditions of formation, even of very simple terrestrial substances, is still extremely limited. This statement applies particularly to very slightly soluble substances, the true chemical nature of which is often not definitely established. These are the substances most likely to appear as minerals and are therefore of the utmost geological importance. Some of these very insoluble substances exhibit properties which have been classed as colloidal, and this has led in recent years to the tendency to assign many problems of weathering and sedimentation to the domain of colloid chemistry and to classify the minerals involved as colloids. However, this has in no way added to our real knowledge of the minerals or of the conditions involved in the formation process. Unless the system in which the particular colloidal substance appears can be defined and controlled, except in the more restricted case of sedimentation which takes place in proved suspensions, excursions into the uncertainties of colloid chemistry can hardly be of any real value at present. What is most needed is the accumulation of exact knowledge of the properties and behavior of the substances involved. This may be difficult and is often discouragingly slow,

¹ Situated in Washington, District of Columbia.

* Eugene Posnjak, George Tunell.

but is just as necessary as in the case of rock formation from the magma; in both cases phase-rule studies of the systems involved are essential to supply basic facts.

Such studies have now been in progress for some time with attention chiefly directed to processes taking place in the so-called oxidation zone overlying iron and copper sulfides. Pyritic ores are readily oxidized in contact with water and air, with the accompanying formation of solutions containing ferrous and ferric sulfate and sulfuric acid, which in turn attack the copper sulfide and the surrounding rock. During this process a number of new mineral species are produced, such as goethite, hematite, basic and normal sulfates of iron and copper, etc. Most of these were insufficiently known, so that it was even uncertain which ones of the great number of substances mentioned by the various investigators were definite compounds and which were merely mixtures of certain difficultly soluble fine-grained substances. The results of the study of the system $\text{Fe}_2\text{O}_3\text{-SO}_3\text{-H}_2\text{O}$, reported several years ago, cleared away a number of these uncertainties. They proved the applicability of phase-rule studies to the processes of weathering and sedimentation by definitely establishing, for example, some of the conditions of formation of goethite and hematite, where previously, unless present in distinct crystals, they were treated as variable forms of colloidal oxides of iron.

The investigation of such very slightly soluble substances, both laboratory and natural products which usually appear in an extremely fine-grained condition, has quite recently been greatly facilitated by the systematic application of the "powder method" of X-ray diffraction for their identification. Much time was usually consumed in the study of such fine-grained material and in the correlation of its properties with the conditions under which it was formed. While some of this expenditure will always remain necessary, the appropriate use of this additional method usually removes many of the uncertainties and insures hastening the progress of this work.

At present, the study of the system $\text{CuO-SO}_3\text{-H}_2\text{O}$ between and including the temperatures 50° and 200° has been completed, defining the properties and the stability relations of copper oxide, brochantite, antlerite and the different normal hydrates, and of anhydrous copper sulfate, which appear as solid phases in this system. Besides the general relations established by this investigation, the data on antlerite and brochantite may furnish specific information concerning some of the conditions of formation of the great copper lode at Chuquicamata, Chile, where these minerals are the chief copper ore.

The two ternary systems just mentioned form the necessary preliminary basis for the partial study of the quaternary system $\text{Fe}_2\text{O}_3\text{-CuO-SO}_3\text{-H}_2\text{O}$, now in progress, which is expected to broaden our understanding of some phases of the processes involved.

Besides the investigation of processes which take place in connection with the oxidation of the iron and copper ore bodies, studies of weathering and sedimentation connected with laterization are at present also in progress. This process consists mainly in the formation of deposits of hydrated and anhydrous oxides of iron and alumina, which apparently are derived from

the decomposition of such rocks as granite, basalt, diorite, etc., accompanied by the removal of the silica. The first step was to establish definitely the various hydrated and anhydrous forms of alumina and to determine their properties. Of these, gibbsite, diaspore, corundum and β - Al_2O_3 have long been well known; the nature of bauxite was established a few years ago by J. Boehm and our studies confirm its composition as $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$. Bauxite has now been prepared in this Laboratory in well-defined crystals and its optical and crystallographic properties will soon be definitely established. The substance recently described as a second modification of $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ had been independently obtained in the present investigation, but the available data indicate that its composition is rather that of a two-hydrate. The optical and crystallographic properties of the third modification of alumina, γ - Al_2O_3 , also only recently discovered, apparently have not been correctly determined by previous investigators. It is hoped to complete the data concerning these substances in the near future.

In connection with the study of the hydrated oxides of alumina a preliminary examination of so-called bauxites from various localities revealed that in the majority of cases the chief mineral was not bauxite at all, but gibbsite. This suggests that true bauxite deposits are possibly comparatively rare, and it seems at least probable that the conditions required for their formation are very different from those in which gibbsite is formed.

It may be reported further, that the study of the system Al_2O_3 - SO_3 - H_2O is well under way and it is hoped will establish the conditions of stability of some of the alumina minerals in question. A basic salt of the composition $3\text{Al}_2\text{O}_3 \cdot 4\text{SO}_3 \cdot 9\text{H}_2\text{O}$ has also been prepared and its stability partly determined. The properties of this substance have been measured and found to be very similar to those of the mineral alunite. Indeed it is thought likely to occur in nature, and may have been mistaken for alunite. The stability relations of the latter, which are of considerable geological interest, should be defined by the investigation of the quaternary system Al_2O_3 - Na_2O - SO_3 - H_2O which study is contemplated for the near future.

FIELD ASPECT OF THE PROBLEM¹

The ridges and knolls of rock laid bare at the earth's surface are, in time, profoundly altered by rain and wind. Abundant products of this process are compounds of iron and oxygen, pigments with which nature has colored the western landscape in countless shades of brown and red. Over the Cordilleran slopes prospectors hunted with close scrutiny of the altered ledges for the red oxide and green carbonate ores of copper, and discovered many rich pockets and lodes. Under the ledges still richer veins of sulfide ore were opened. In recent years, with the exhaustion of the veins, the adjacent porphyritic rocks finely sprinkled with grains of iron and copper sulfide have been utilized as low-grade ore to fill the growing needs of industry.

The possibility of a correlation between the surface rock and the underlying low-grade porphyry ore has a special geologic cause. The rock now exposed at the land surface formerly contained disseminated grains of iron

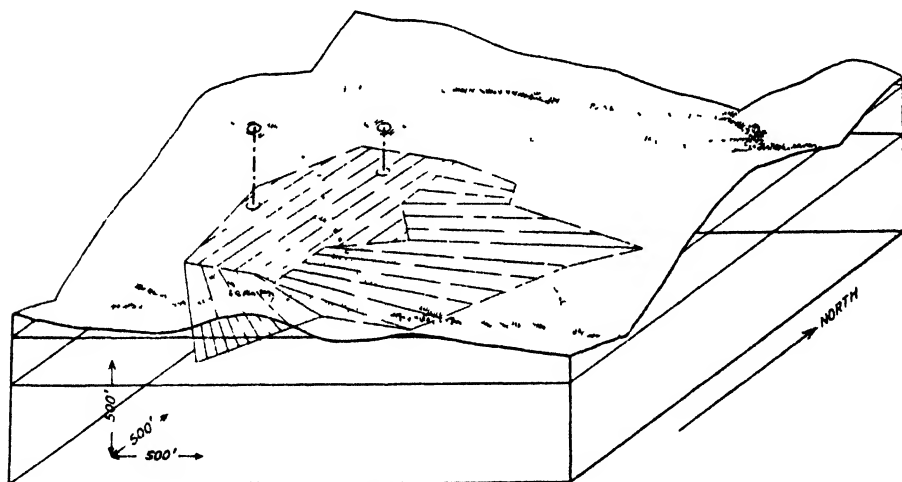
¹George Tunell.

and copper sulfide. As the mountain slopes were disintegrated and worn away by thermal expansion, wind and rivulets, part of the water seeped into the ground, dissolving the ore minerals and bearing downward part of the sulfuric acid, part of the iron and nearly all of the copper. The copper did not all escape from the immediate locality, however, but was reprecipitated at greater depth, thereby adding to the richness of the original sulfide-sprinkled rock. At the same time most of the iron remained at its original level, forming a vestige of the oxidation-enrichment process eventually uncovered by the erosion of the mountain slope.

Since the oxides of iron are present in small amount in almost all of the surface rocks, coloring them various shades of brown and red, and since iron sulfide is sprinkled through the buried porphyry in many places unaccompanied by the more valuable copper sulfide, the interpretation of the iron-oxide vestiges left by the oxidation-enrichment process above the hidden low-grade ore masses is difficult.

Discoveries of ore bodies through the coloration of the overlying outcrops caused Locke to undertake a thorough investigation of leached outcrops as guides to copper ore. In collaboration with Dr. Locke a detailed study of the oxidation process has been made in two western districts. A number of columnar sections penetrating the contact between the zones of oxidation and enrichment were selected as representative. The columnar sections had been sampled and assayed for copper at intervals by the mining companies and the geologic structure along them was mapped by us. Along each section samples were secured from freshly exposed surfaces at vertical intervals of one foot. Thin sections and polished sections of each sample were examined under the petrographic and reflecting microscopes, and hand specimens were studied under the binocular microscope to trace the changes from the sulfide-sprinkled ore to the barren leached capping, and to determine further changes, if any, in the oxidation products themselves in the capping between the top of the ore and the land surface. The minerals formed by the oxidation process were identified as goethite, hematite and jarosite by quantitative measurement of the refractive indices, by observation of the optical orientation and the color in grains of measured thickness and by qualitative chemical tests. In many cases the entire change from entirely unoxidized sulfide-sprinkled ore to completely oxidized capping was observed within a microscopical field $1/8$ inch in diameter, one side of the field being dotted with iron and copper sulfides with no oxidized iron minerals, the other side of the field with no sulfide grains but dotted with cavities of the same sizes and shapes as the sulfide grains in the first side, these cavities being partly filled with goethite, hematite, or jarosite or mixtures of these minerals in various proportions. In the oxidized or capping side of the microscopical field there were also scattered through the gangue varying amounts of the goethite, hematite and jarosite in minute spherulites and euhedral crystals much smaller than the sulfide grains in the ore side of the field. Detailed records of the minerals and their microscopical structures were made. Thus it was learned that the oxidation products in part replaced the sulfides, but in part replaced the gangue.

Rough correlations were found between the proportion of iron sulfide to copper sulfide, and the total proportion of sulfides in the ore on the one hand and the proportion of oxidized iron minerals left in the sulfide cavities to those which replaced gangue, the proportion of goethite to hematite, and the proportion of goethite to jarosite on the other hand. Part of the correlations found had been previously discovered by Morse and Locke and merely constituted verifications. The others had not been stated previously but are believed to have been foreshadowed by somewhat vague and in different districts apparently opposite observations, partly recorded in the literature and partly reported locally. The ore and cappings referred to have in numerous cases been reexamined in the field and laboratory in the light of the mineralogic knowledge yielded by the microscope, and it appears probable that the observations were correct while the apparently opposite conclusions arrived at were due to the statement of the observations in terms of 2 color designations where 3 colors were really present. Thus Ransome¹ states that at Ray and Miami, Arizona, "a deep and conspicuous redness of the surface is less propitious than a rather subdued tint of rustiness." Blanchard² from studies in Silverbell (Arizona), Santa Rita (New Mexico), Tyrone (New Mexico), Morenci (Arizona), Plumas County (California), and various



Stereogram of Clay Ore Body, Morenci, Arizona
Columnar sections are represented by lines of dashes and dots

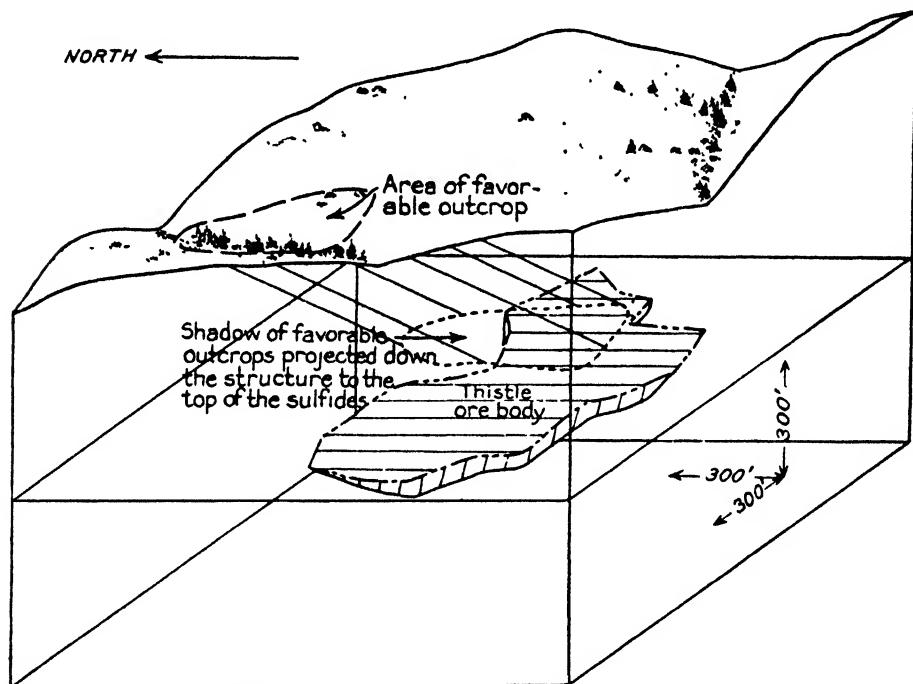
places in Sonora and British Columbia, concludes that in the field the capping over known disseminated ore usually has a deep maroon to seal-brown color and that the bright red or brick-red cappings have nowhere been observed except over pyritic areas where the copper content of the enriched zone, as a whole, averaged much less than 0.5 per cent copper. He concludes further that not all of the low-grade pyritic areas are overlain by brick-red cappings but the brick-red capping has nowhere been found over actual ore ground. E. M. Sawyer³ found that at Tyrone, New Mexico, reddish-brown

¹ *The Copper Deposits of Ray and Miami, Arizona*, U.S.G.S. Prof. Paper 115, 165 (1919).

² Private communication to the authors, later published in *Leached Outcrops as Guides to Copper Ore*, by Augustus Locke, 114 (1926).

³ Private communication.

cappings are underlain by ore in more cases than yellowish-brown ones, and Paige¹ has made the same statement for this locality. Our observations are that capping containing hematite as a replacement of gangue has a brick-red color and is correlated with pyritic waste; capping containing hematite and goethite in the cavities left by the sulfides has a maroon to seal-brown color and is correlated with ore or at least with protore in which the proportion of copper sulfide to iron sulfide is high; capping containing goethite and jarosite as replacements of gangue has a yellowish-brown color and is correlated with pyritic waste. In a given district the unfavorable capping is for the most part all of the brick-red type or all of the yellowish-brown type. The confusion appears to have been caused by the fact that single observers did not happen to see both types of deposit.



Stereogram of Thistle disseminated chalcocite-pyrite ore body, Tyrone, New Mexico ²

The correlations observed merely express the results of the oxidation process which took place in different mixtures of iron and copper sulfides in relatively but not completely inert gangues. From them we have inferred certain details of the chemical oxidation process, and hence predicted certain equilibrium relations in the portion of the system ferric oxide-cupric oxide-sulfur trioxide-water in which the water concentration is high. These relations are now being determined as a check on the practical correlations and geologic deductions. The investigation of the fundamental system ferric oxide-sulfur trioxide-water was carried out some time ago³ and that of the system cupric oxide-sulfur trioxide-water has just been completed.

¹ *Copper Deposits of the Tyrone District, New Mexico*, U.S.G.S. Prof. Paper 122, 39 (1922).

² Area of favorable outcrops by Boswell.

³ Posnjak and Merwin, Reviewed in Year Book No. 21, 147.

The investigation of the small portion of the 4-component system involved is now being carried out.

ACID GASES AND INCRUSTATIONS IN THE VALLEY OF TEN THOUSAND SMOKE¹

Among the most interesting results from the study of the Valley of Ten Thousand Smokes is the observation that the steam issuing from the fumaroles contained about 0.4 per cent of a complex mixture of volatile materials, about one-half of which was made up of hydrochloric acid, hydrofluoric acid and hydrogen sulfide. The precise amounts emitted were:

Estimated volume of steam exhaled by fumaroles= 26×10^6 liters per sec. (100°, 760 mm.).

Steam contains:

0.117 p. ct. HCl
0.032 p. ct. HF
0.029 p. ct. H₂S

These amounts are equivalent to:

36.0 kg. HCl per sec.
5.6 kg. HF
8.4 kg. H₂S

Amount in tons per year:

HCl= 1.25×10^6
HF= 0.2×10^6
H₂S= 0.3×10^6

If we assume that these acid gases have their origin in the intruded magma beneath the Valley they doubtless suffer a certain amount of modification in their passage upward through a considerable thickness of overlying pumice, and perhaps also from the drainage water which reaches the bottom of the Valley. The temperatures of some of the fumaroles measured at the surface in 1919, five years after the eruption, exceeded 500° C. It may therefore fairly be assumed that temperatures at the source were higher than this, and that steam and acid gases discharged at these high temperatures constitute a powerful chemical agent through which to dissolve and sweep out other volatile materials which were encountered in their upward journey. The incrustations with which these cracks and fumaroles are lined carry the record of the powerful solvent action of these gases, and the detailed study of these has been particularly instructive in showing how superheated steam may carry with it, in vapor phase, metallic sulfides and oxides which are then deposited in some neighboring region at lower temperature, or carried out into the atmosphere. A part of the interest of such studies is to be found in the power of such an agency to remove, translate and eventually to concentrate valuable ore deposits. Whether this be the most effective agency for this purpose or not is perhaps still an open question, but the power and rapidity of its action (rate of deposition) is adequate to effect the

¹ E. G. Zies.

translation of considerable bodies of material in an extremely short time, as geologic time is reckoned. In the Valley of Ten Thousand Smokes alone the amount of material moved in vapor phase is computed in millions of tons in the short period between 1912 and 1919. The details of these phases of the subject do not admit of rapid review and may properly be left for discussion at another time and place.

It is, however, of immediate and general interest to consider certain of the more general consequences of discharging into the atmosphere 1,250,000 tons annually of hydrochloric acid gas and 200,000 tons of hydrofluoric acid gas. These substances must eventually find their way into the sea, and the accumulating salt content of the sea has formed one of the important measures of geologic time and otherwise has been the subject of active study among geologists for a century or more. It is a matter of repeated observation that the average river water flowing into the sea contains much less chlorine than is necessary to satisfy its sodium content; the ocean waters on the other hand contain much more chlorine than sodium. Suess and Becker long ago suggested that the difference may have been made up by chlorine from volcanic emanations, but their figures were hypothetical and perhaps have not proved generally convincing. As more detailed studies of volcano gases came to be made (Hawaii) it appeared that chlorine formed but a very insignificant portion of its gaseous output. The Valley of Ten Thousand Smokes discharges a much greater proportion of these gases. Enlightenment comes, however, when we begin to consider the aggregate quantity of even the least significant of the volatile ingredients when continually discharged into the atmosphere at these rates. Becker has made the interesting calculation that if one hundred million tons of hydrochloric acid were uniformly distributed throughout the atmosphere and dissolved in rainfall to an aggregate of one meter thickness, this precipitation would contain less than one-fifth of a millionth part of chlorine. One part in a million would be accounted insignificant as a problem in chemical determination, nevertheless the fifth part of this yields the one hundred million tons which is about the aggregate annual requirement to account for the saltiness of the sea. Of this one hundred million tons therefore the Valley of Ten Thousand Smokes alone was contributing more than one per cent in 1919. Kilauea, whose chlorine output was accounted particularly insignificant, contributed some 30,000 tons annually. When to these are added the numerous volcanoes, both occasional and persistent, whose gaseous output is characteristically acid (Katmai, Martin, Iliamna in Alaska; Vesuvius, Etna in Italy; Cotopaxi in Mexico; Pelée in Martinique; etc.), it appears that the recent measurements tend to confirm the earlier hypothesis that a significant part of the chlorine content of the sea is of volcanic origin. The discharge of hydrochloric acid from volcanic sources may vary from year to year and from one geological period to another, but there are many areas, so far as one may judge from printed descriptions, where the amount of hydrochloric acid gas in the steam is of the same order of magnitude as in the Valley of Ten Thousand Smokes.

It has been suggested that chlorine in volcanic gases is derived from infiltrated sea-water and hence the chlorine in the hydrochloric acid given

off during an eruption is simply being returned to its source. R. T. Chamberlin has called attention to the fact that if such infiltration of sea-water could take place we should expect a considerable evolution of hydrochloric acid during the active periods of Kilauea, a volcano of very porous structure situated in the ocean. Nevertheless its chlorine output is among the smallest of record. When to this is added the laboratory evidence of Johnston and Adams, that if sea-water reaches the volcano conduit at high temperature it must do so as gas, and in this condition its internal friction is such that it could scarcely make progress at all in capillary spaces at volcano temperatures and against the pressure of the lava column, this idea must perforce be abandoned for the present.

Our conclusion therefore appears established that the discharge of acid gases from volcanoes is at least of the proper order of magnitude to supply the additional chlorine which is characteristic of the ocean as compared with the rivers.

The probable history of the fluorine discharge is chemically more complicated and somewhat more difficult to trace. Fluorine was found in every incrustation examined from the Valley of Ten Thousand Smokes in amounts varying from 0.1 per cent to 15 per cent, the higher percentages being characteristic of areas of higher temperature. There is therefore some reason to assume that a larger proportion of the fluorine is locked up in the incrustations, and the total amount of discharged fluorine is not greatly different from that of chlorine. The fluorine content of the sea is about 0.8 mg. per liter, whereas that of chlorine is 19.3 grams per liter. The disparity between these figures points to two obvious conclusions: (1) That a very much larger proportion of the fluorine becomes fixed in other ways or en route and is not accumulated as such by the ocean to anything like the same degree as chlorine. (2) The source of volcanic fluorine can hardly be the ocean. Should there be any disposition to insist that there is still a probability that the chlorine of the volcanoes has its source in the infiltration of sea-water, then the fluorine content must be assumed to have the same origin. This appears extremely unlikely if the discharge of the two gases from the Valley of Ten Thousand Smokes is of the same order of magnitude, while in the assumed source (the ocean) they are of a totally different order. The selective retention of halides by the basic elements in the lava can not here be invoked, for at the high temperatures prevailing near the lava column steam will sweep out both the chlorine and the fluorine.

All of the evidence available to us in respect to hydrochloric and hydrofluoric acid gases from volcano sources indicates that the halogens are derived from the lava itself or from adjacent rocks through which the steam and acid gases pass.

From the table it appears that approximately 200,000 tons of hydrofluoric acid are contributed annually to the sea from the one volcanic area. The fluorine content of the ocean is not known with certainty. One investigator finds 0.2 mg. per liter, another 0.8 mg. per liter, the difference being more probably due to the difficulty inherent in the determination of small amounts of fluorine than to differences in the concentration of sea-water. If the total volume of the ocean be assumed with Kossinna to be 1,370,323,000

cu. km. and the fluorine content to be 0.8 mg. per liter, then a cubic kilometer of sea-water contains 0.8×10^8 metric tons of fluorine, and the entire fluorine content of the ocean could have been contributed by an area smaller in size than the Valley of Ten Thousand Smokes in about eight million years. This is a period much shorter than the lowest estimate for the age of the ocean, and fluorine is contributed to the sea not only from volcanoes but from rivers as well.

It is probable that fluorine and chlorine have been supplied to the ocean from volcanoes in substantially the same order of magnitude, the chlorine has been permitted to pass while the fluorine has been fixed on the way, presumably by virtue of the insoluble compound formed with calcium and by the relative ease with which fluorine can be precipitated when other substances are present. There is abundant evidence that fluorine is removed from sea-water long before the water is saturated with respect to the substance most likely to precipitate, namely, calcium fluoride. The teeth, bones and shells of marine animals contain fluorine, and it has been shown that calcium phosphate is an effective agent in removing even traces of fluorine from a solution. It is practically impossible to form an estimate of the amount of fluorine and phosphorus that is removed from the sea through these biochemical processes, but it is certain that the amount must be very great. Mansfield in his able monograph, lately published, on the phosphate beds of southeastern Idaho, gives an excellent account of the agencies that were probably involved when the phosphatic material of the ancient Phosphoria Sea was deposited. If these be characteristic of the fluorine content of ocean sediments, then the amount of fluorine fixed by coprecipitation with phosphates is very large. According to Wyatt the average fluorine content of the phosphates is 1.5 per cent. Mansfield states that every analysis of the western phosphates showed the presence of fluorine. The amount of high-grade phosphate in one section was placed by him at 83,000,000 metric tons. The analysis of this material showed 0.9 per cent fluorine. This amounts to 750,000 metric tons of fluorine. On this basis the fluorine content on the high-grade phosphate alone of this great area amounts to 54,000,000 metric tons, with practically nothing yet known of the fluorine content of the low-grade phosphates. Other well-known sedimentary phosphate beds are found in Northern Africa, Russia and Siberia, in some of which still higher percentages of fluorine have been discovered.

These huge figures reveal to us with considerable positiveness the disposition of the volcanic fluorine discharged into the atmosphere. It is seized and side-tracked, as it were, by chemical and biochemical fixation, and is not now to be sought in the ocean. There is therefore no apparent reason for considering the measured and unexpectedly large fluorine content of the fumaroles of the Valley of Ten Thousand Smokes to be doubtful or abnormal. The figures appear to be of the right order of magnitude.

PUBLICATIONS

- (648) Die Kristallstruktur von Zirkon und die Kriterien für spezielle Lagen in tetragonalen Raumgruppen. Ralph W. G. Wyckoff and Sterling B. Hendricks. *Z. Krist.* 66, 73-102. 1927.

Crystals of zircon have the symmetry of the space group $4D_{19}(D_{4h}^{19})$. The unit cell contains four molecules and has the following dimensions: $a_0=6.60 \text{ \AA}$, $c_0=5.88 \text{ \AA}$. It is shown that the atomic arrangement prevailing in these crystals must be expressed by the following special positions of $4D_{19}$: Zr atoms at (a), Si atoms at (b), O atoms at (h) with $0.18 < u < 0.21$ and $0.30 < v < 0.34$. The most probable parameter values are $u \approx 0.20$ and $v \approx 0.34$.

Distinguishing criteria are listed for each of the special cases of the tetragonal space groups.

- (649) On liquid immiscibility in the system $\text{FeO-Fe}_2\text{O}_3\text{-Al}_2\text{O}_3\text{-SiO}_2$. J. W. Greig. *Am. J. Sci.* 14, 473-484. 1927.

In an earlier paper (See No. 630) it was shown that a number of oxides are but partially miscible in the liquid state with silica. Siliceous mixtures of these oxides with silica form two liquids on melting. On the other hand there are certain oxides, notably alumina, soda and potash, which do not exhibit this behavior. Moreover, the introduction of a small amount of one of these latter oxides is sufficient to cause a mixture, which would otherwise form two liquids, to melt to a single homogeneous liquid. It was shown that the compositions of igneous rocks could not be accounted for by the compositions of the immiscible liquids so formed. All the important rock-forming oxides with the exception of Fe_2O_3 were considered in that paper, namely, CaO , MgO , FeO , Al_2O_3 , Na_2O , K_2O , SiO_2 .

The present paper outlines an extension of the experimental work. The limits of immiscibility at the temperature of complete melting have been determined for a part of the system $\text{FeO-Fe}_2\text{O}_3\text{-Al}_2\text{O}_3\text{-SiO}_2$. The results show that the equilibrium conditions here are similar to those in the other systems studied. In the ternary system $\text{FeO-Fe}_2\text{O}_3\text{-SiO}_2$ an increase in the ratio of ferric to ferrous oxide up to the one to one ratio (the limit of the experimental work) is accompanied by a divergence in the compositions of the two immiscible liquids which may exist in equilibrium with cristobalite, that is, which are formed on melting. This is accompanied by a slight decrease in the temperature of the equilibrium. As in all the examples of this phenomenon which have been studied, the introduction of alumina is accompanied by the convergence of the compositions of the two liquids, and when but a small percentage is added only one liquid is formed on melting.

No support is found in the experimental work for the hypothesis of the differentiation of magmas by splitting into immiscible liquids.

The behavior of silica brick in the roof of the open-hearth steel furnace is briefly considered in the light of the experimental results.

- (650) Papers presented at the 1927 meeting of the Section of Volcanology, American Geophysical Union. *Bull. Nat. Research Council* 61, 255-269. 1927.

This report contains the record of seven short papers, of which six were presented by members of the Laboratory. These are:

- (1) The work of the Geophysical Laboratory on hot springs. E. T. Allen. Pages 255-259.

A brief review of the more important conclusions following from the work of the Geophysical Laboratory on the last stages of volcanism.

- (2) The present status of the volcano-gas problem. E. S. Shepherd. Pages 259-263.

The compositions of the gases collected from the lava lake at Kilauea are practically identical with those still retained in solution by the chilled lava and in no significant way different from those obtained by heating in vacuo the properly collected lava of other volcanoes. In all cases H_2O is the dominant constituent, averaging about 80 per cent of the total volatiles. In all cases the gases reach the earth's surface with their chemical energy practically exhausted. While gas reactions may play an important rôle in maintaining the mobility of the lava on its upward journey, they are incapable of supplying enough energy to account for the observed phenomena without requiring the rapid movement of incredible amounts of gas through the lava.

The author regards the basaltic volcanoes as the primary source of volcanic energy, while the andesitic and more acid volcanoes are secondary phenomena operating by a different mechanism. The Kilauea lake is regarded as a lava spring with subterranean drainage. The concept of circular conduits leading directly to large magma chambers is held to be misleading.

- (3) The concentration of metallic constituents by volcanic emanations. E. G. Zies. Pages 263-265.

An abstract of a paper about to be published on the concentration of metallic constituents by means of the vapor-phase activity of an igneous body.

- (4) The present status of Santorini. H. S. Washington. Page 266.

Brief note only.

- (5) Research work in volcanology in Japan. Arthur L. Day. Page 266.

An informal report of which no record was made.

- (6) Factors bearing on the formation of craters on the moon. F. E. Wright. Pages 266-269.

Before undertaking a serious investigation into the genesis of the surface features of the moon, the geologist must first ascertain the nature of the materials exposed on its surface and then their behavior under the conditions that exist there. With this information at hand it will be possible for him to attack the problems of the physiography of the moon with some prospect of success, but not until then. In this short paper a summary is given of the present status of the problem.

- (651) A note on the change of compressibility with pressure. Leason H. Adams. J. Wash. Acad. Sci. 17, 529-533. 1927.

It is sometimes impracticable to determine the amount by which the compressibility of a solid changes with pressure, even though the mean compressibility over a given pressure range may have been measured with considerable accuracy. From an examination of existing data on the change of compressibility with pressure it is shown that for crystalline solids this change of compressibility is to a rough approximation dependent on the compressibility itself. The relation is more obvious if the halides be excluded; the remaining observations lie fairly well on the smooth curve. This curve

may therefore be used to estimate the pressure-coefficient of compressibility if the mean compressibility over a given pressure-range is known, and will probably be of practical value in connection with the extrapolation of compressibilities of rocks and other solids to pressures above the experimental range.

- (652) Rocks of the Galápagos Islands. H. S. Washington and Mary G. Keyes. J. Wash. Acad. Sci. 17, 538-543. 1927.

Two new analyses are given of rocks from the islet of Eden, off the north-west coast of Indefatigable. One is that of a normal andesine basalt, similar to several Hawaiian basalts. The other is the so-called palagonitic tuff of the earlier writers, consisting mainly of a yellow glass, similar to the tuffs of the island of Linosa. The lavas of the Galápagos are more complicated and varied than has generally been supposed, and there is much similarity between them and the lavas of most of the Intro-Pacific volcanic islands.

- (653) The crystal structure of potassium. E. Posnjak. J. Phys. Chem. 32, 354-359. 1928.

Contrary to former statements, normal diffraction effects are obtained from potassium at room temperature by the powder method.

The reason for obtaining only a general scattering and no definite diffraction in former experiments is thought to be the formation of films on the sample of potassium by moisture, by oxidation, or by interaction of the potassium with the glass.

The method used for the preparation of samples of potassium is described.

The available data indicate that potassium crystallizes in the body-centered cubic lattice. The length of the edge of the unit cube containing two atoms of potassium is 5.333 ± 0.005 Å. The calculated density is 0.851.

The lengths of the edges of the unit cubes of sodium and lithium were redetermined and, in agreement with earlier determinations, the value obtained for the former was 4.30 Å and for the latter 3.51 Å.

- (654) The common earths. Robert B. Sosman. Annual Survey of American Chemistry, vol. 2 (1926-1927), 123-129 (chapter 13). 1927.

The principal American research work on the chemistry and the properties of the oxides SiO_2 , Al_2O_3 , MgO , CaO , Fe_2O_3 , and FeO , and their compounds and mixtures with each other, is briefly summarized. This set of oxides is given separate discussion for the first time in Volume 2 of the "Survey," and the period reviewed therefore covers approximately the years 1925 and 1926, and the first half of 1927.

- (655) Glass. George W. Morey. Annual Survey of American Chemistry, vol. 2 (1926-1927), 299-306 (chapter 39). 1927.

A summary of new developments during the years 1924 to 1927 in the chemistry and technology of glass.

- (656) Petrology of the Hawaiian Islands: VI. Maui. Henry S. Washington and Mary G. Keyes. Am. J. Sci. 15, 199-220. 1928.

Analyses and petrographic descriptions of eleven specimens of rocks from Maui are presented, together with one analysis of a lava from Molokai. There are two volcanoes. The older, Kukui, furnished specimens (4 analyses) of lavas from points within the volcano as well as from surface flows. The younger, Haleakala, furnished 7 analyses of lava from recent flows only.

The lavas of Maui, like those of all the other Hawaiian Islands, are predominantly andesitic and basaltic, yet they show a distinct alkalic tendency. Averages show potash and especially soda to be distinctly higher than in the rocks of Hawaii or the Leeward Islands. This fact and the abundance of trachytic and nepehelinic rocks at Maui give further emphasis to the irrationality of a classification of igneous rocks into "Atlantic" and "Pacific" suites. One of the most significant features of the general petrology of Maui is the difference in the lavas and in their succession at the two volcanoes.

This paper is one of a series describing the petrology of the whole Hawaiian group (see Annual Report for 1925-26, p. 80).

- (657) P-T-X relations for systems of two or more components and containing two or more phases (L-V, L_1 - L_{II} -V and S-L-V systems). F. C. Kracek. International Critical Tables 3, 351-385. 1928.

An extract from the third volume of the International Critical Tables.

- (658) On the evidence which has been presented for liquid silicate immiscibility in the laboratory and in the rocks of Agate Point, Ontario. J. W. Greig. *Am. J. Sci.* 15, 375-402. 1928.

This paper was written in reply to an article by T. L. Tanton (*Am. J. Sci.* 15, 66-68, 1928) in which some criticism was made of the evidence presented by Greig for immiscibility in silicate melts and an analogy drawn between that evidence and the evidence which Tanton had presented for liquid immiscibility in a lava flow at Agate Point, Ontario. (T. L. Tanton, *J. Geol.* 33, 629-41, 1925.)

The points bearing on the laboratory evidence are first taken up. The rock of Agate Point, which is a porphyritic rhyolite or obsidian, is then considered and the conclusion, based on field and laboratory study, is arrived at, that the phenomena which Tanton attributed to the splitting of a lava into two immiscible liquids are due to spherulitic crystallization.

- (659) Lead isotopes and the problem of geologic time. Charles Snowden Piggot. *J. Wash. Acad. Sci.* 18, 269-273. 1928.

The reliability of the uranium-lead ratio method of determining geologic time is greatly weakened by the inability of the method, as now employed, to distinguish between that lead which came from uranium and other leads which did not. The formula now being used is probably inaccurate because of the uncertainty of the thorium disintegration series.

The paper discusses a procedure which meets both these uncertainties by identifying and determining the principal isotopes of lead: 206, from uranium; 207 ("ordinary"); and 208, from thorium.

A direct relationship between the uranium and its own lead can thereby be obtained; the thorium content may be ignored or its relationship definitely established for a future formula.

Incidentally to the main object of the investigation, the isotopes of lead were determined for the first time.

- (660) The radium content of Stone Mountain granite. Charles Snowden Piggot. *J. Wash. Acad. Sci.* 18, 313-316. 1928.

This is a preliminary paper announcing a proposed comprehensive investigation of the radium content of the rocks of the Earth's structure. The investigator seeks to correlate the radium content with all other known facts chemical, petrographic and geologic, which are obtainable about each

rock studied. By this means it is hoped that there may be secured more definite information concerning the part played by radium in geologic phenomena.

The paper deals more particularly with a description of the granite from Stone Mountain, Georgia, and of the apparatus and technique used.

Sixteen determinations are given of the radium content of this granite which was used for the calibration and standardization of the apparatus and technique.

(661) The atomic arrangement in crystals of the alkali platini-thiocyanates. Sterling B. Hendricks and Herbert E. Merwin. *Am. J. Sci.* 15, 487-494. 1928.

Laue and spectrum photographs have been made from crystals of ammonium, rubidium and potassium platini-thiocyanates. Crystallographic measurements were made on the potassium and ammonium salts. The crystals are hexagonal with the axial ratios $a : c = 1 : 1.32$ (K), and $a : c = 1 : 1.35$ (NH_4). These measurements are compatible with the X-ray measurements but not with the previous crystallographic description.

The hexagonal units of structure containing $1 \text{ R}_2\text{Pt}(\text{SCN})_6$ have the dimensions (in Ångstrom units):

	a	c
NH_4	6.77	10.45
K	6.73	10.26
Rb	6.75	10.47

The space group is 3Di-1 or 3Di-3. The sulphur atom of an (SCN) group is probably adjacent to the platinum atom. The derived structure is similar to that of CdI_2 .

(662) The density of Hawaii and density distribution in the Earth's crust. Roy W. Goranson. *Am. J. Sci.* 16, 89-120. 1928.

The writer's attention was first attracted to this subject in attempting to calculate the density of the rock mass composing the Hawaiian Islands. In order to bring the measured rock mass densities into agreement with those deduced from gravitational data it was found necessary to make a more extended study of these relationships.

The hypothesis of isostasy is assumed to correct for the differences between the observed values of gravity and those computed from the shape of the Earth corrected for deviations of surface configuration. After consideration of the physical and geological restrictions which any hypothesis for computing isostatic compensation must satisfy, a form of the Airy hypothesis was adopted as being the most acceptable.

This adopted form leads to results which, for gravity stations in the United States, are just as satisfactory as those obtained from the Pratt-Hayford hypothesis. It leads to density values lying between 2.4 and 2.6 for the rock mass composing the island of Hawaii. Moreover, the conclusion is that the volcanic islands of the Pacific are essentially uncompensated (sinking) loads on the sub-Pacific crust.

(663) The influence of pressure on the high-low inversion of quartz. R. E. Gibson. *J. Phys. Chem.* 32, 1197-1205. 1928. A note on the high-low inversion of quartz and the heat capacity of low quartz at 573° *Ibid.*, 1206-1210.

INFLUENCE OF PRESSURE ON THE HIGH-LOW INVERSION OF QUARTZ

When quartz is subjected to a uniform hydrostatic pressure of p megabaryes, the temperature of its high-low inversion is raised according to the

following equation: $\Delta T = -0.3 + 2.1 \times 10^{-2}p + 8.6 \times 10^{-7}p^2$. This equation expresses the results of direct experimental observations made between 0 and 3,000 megabaryes. From the initial pressure coefficient and the instantaneous volume change during the transformation it follows that the latent heat of inversion is 3.1 cal. per gram.

A NOTE ON THE HIGH-LOW INVERSION OF QUARTZ AND THE HEAT CAPACITY
OF LOW QUARTZ AT 573°

Although the high-low inversion of a crystal of quartz is a phase change usually accompanied by superheating or undercooling, there is a temperature ($572.3 \pm 0.2^\circ$) at which low quartz may be converted reversibly to high quartz. This is regarded as the equilibrium temperature of the reaction.

In general, however, before a block of low quartz passes to the high form it superheats so much that during the inversion its temperature never falls to the equilibrium value. This enables us to estimate the apparent heat capacity of low quartz in the vicinity of 573° . The value obtained is 4 ± 1 cal. per gram per degree.

(664) Natural steam power in California. E. T. Allen and Arthur L. Day. *Nature* 122, 17-18, 27-28. 1928.

A brief popular article on the subject treated in No. 642 (Annual Report, 1926-27, p. 76).

(665) Annual Report for this year.

(666) The analytical determination of uranium, thorium, and lead as a basis for age-calculations. Clarence N. Fenner. *Am. J. Sci.* 16, 369-381. 1928.

For calculations of geologic age from the content of uranium, thorium and lead in a mineral a correct analysis is a fundamental requisite, but the minerals in which these elements occur are often of such composition as to present special difficulty to the analyst.

In this paper detailed descriptions of methods of analysis are given, which have been found in practice to work well and to give apparently reliable results. They are offered for the consideration of analysts who have had experience with similar material.

(667) Radioactive minerals from Divino de Ubá, Brazil. Clarence N. Fenner. *Am. J. Sci.* 16, 382-391. 1928.

In a collection of radioactive minerals from Brazil, specimens of monazite, a thorium mineral containing little uranium, and of samarskite, a uranium mineral nearly free from thorium, were subjected to a preliminary treatment to remove decomposition products, and were then analyzed for uranium, thorium and lead as a basis for calculations of age. With both minerals the results indicate an age of about 360,000,000 years. This is believed to be very close to the correct figure, but there are uncertainties due to various causes, and especially to some question as to whether the preliminary treatment had completely removed decomposition products. These matters are discussed, and emphasis is laid on the importance in all work of this kind of seeing that decomposition products be removed as completely as is practicable. It is believed that unless careful attention is paid to this matter misleading results are likely to be obtained.

(668) A model to illustrate the operation of the Foucault pendulum. F. E. Wright and F. H. Schloer. *J. Opt. Soc. Amer.*, etc. 17, 119-126. 1928.

That the Earth rotates on its axis once every twenty-four hours is now so well known that it is difficult for us to realize that only a few centuries

ago many strange surmises were made in the endeavor to explain the daily passage of the Sun, Moon and stars across the heavens. Ancient mythology ascribed these movements to the activities of gods and goddesses.

Emerging from this twilight of imagination into the clearer light of reason, men tried to solve the riddle in a more rational way. In 1851 Leon Foucault devised a method to prove that the Earth is rotating. His demonstration was at once so simple and so convincing that it has been thought worth while to make a model illustrating the operation of the pendulum which he used, and to install it in the Science Exhibition at the National Academy of Sciences and National Research Council in Washington.

This paper describes and illustrates the model as installed and operated.

(670) The evolution of the igneous rocks. N. L. Bowen. x+338 pp., 82 figs., Princeton. 1928. (Princeton University Press.)

This volume is based on a brief course of lectures given to advanced students in geology at Princeton University in the spring of 1927. In these lectures stress was laid on the dominant importance of fractional crystallization in the derivation of igneous rocks from a common source.

The book is divided into two parts. Part I deals with those aspects of fractional crystallization of magmas in which equilibrium diagrams determined in the laboratory are susceptible of fairly direct application to the natural problems. Part II discusses various problems in which the amount of extrapolation from ascertained fact is relatively great or where the diagrams used are mainly hypothetical. The conclusions reached in Part II are thus to be regarded as resting on a less certain foundation than those of Part I. The chapter headings are as follows:

Part I:

- Chapter I, The problem of the diversity of igneous rocks.
- Chapter II, Liquid immiscibility in silicate magmas.
- Chapter III, Fractional crystallization.
- Chapter IV, Crystallization in silicate systems.
- Chapter V, The reaction principle.
- Chapter VI, The fractional crystallization of basaltic magma.
- Chapter VII, The liquid lines of descent and variation diagrams.
- Chapter VIII, The glassy rocks.
- Chapter IX, Rocks whose composition is determined by crystal sorting.
- Chapter X, The effects of assimilation.

Part II:

- Chapter XI, The formation of magmatic liquid very rich in potash feldspar.
- Chapter XII, The alkaline rocks.
- Chapter XIII, Lamprophyres and related rocks.
- Chapter XIV, The fractional resorption of complex minerals and the formation of strongly femic alkaline rocks.
- Chapter XV, Further effects of fractional resorption.
- Chapter XVI, The importance of volatile constituents.
- Chapter XVII, Petrogenesis and the physics of the Earth.
- Chapter XVIII, The classification of igneous rocks.

DEPARTMENT OF HISTORICAL RESEARCH ¹

J. FRANKLIN JAMESON, DIRECTOR

The present report, the twenty-third annual report presented by the present Director of the Department, concerns the period from July 1, 1927, to June 30, 1928. The work of the Department was carried on, as usual, in the rooms in Washington which have been its offices since 1912, with the exception that during July and August the Director, during August the secretary of the Department and Miss McKee, carried on their work at North Edgecomb, Maine.

In respect of personnel, the year has been marked by two important subtractions. At its beginning, Mr. Waldo G. Leland, who for more than twenty-four years had given the Department the benefit of his acute intelligence, energy and resourcefulness, dissociated himself from its active work in order to undertake, technically on leave of absence, the duties of permanent secretary of the American Council of Learned Societies devoted to Humanistic Studies. On November 11, 1927, Dr. Frances Gardiner Davenport, who since October 1905 had devoted herself unremittingly to the work of the Department, was brought by fatal illness to the end of a life consecrated to the most exacting ideals of scholarship. Her reputation as a scholar, already considerable when she came to the Department, was set high by the publication of the first volume of her *European Treaties bearing on the History of the United States and its Dependencies* (Publication No. 234), issued by the Institution in 1917. It will be maintained at the same high level by the eventual publication of her second and third volumes, which were left nearly complete at the time of her death, and are marked by the same solid learning, freedom from bias, thoroughness of investigation and precision and lucidity of statement. But, more than ripe learning and scholarly devotion, her colleagues in the Department, most of whom had been her colleagues for more than twenty years, will remember her elevation of character, her cheerful sympathy, her hospitable and friendly kindness, especially to younger students, and the unflinching and tranquil courage with which she met her fate.

No successor was appointed to either Mr. Leland or Miss Davenport. The Director retires from the service of the Institution at the close of the year now reported upon.

In addition to the regular members of the staff, the Department has had the great advantage of several months of expert assistance from Mr. David W. Parker as temporary member. Mr. David M. Matteson of Cambridge has rendered important service, at appropriate times, as indexer of volumes published. Mrs. Catterall has continued in Richmond and elsewhere, Miss Donnan in Cambridge and Wellesley, Professor Hackett in Austin, their respective lines of work for the Department, the first during the months from October to March, inclusive, Miss Donnan mostly during the summer months, Dr. Hackett at various intervals throughout the year.

¹ Address, No. 1140 Woodward Building, Washington, D. C.

In parts of July and August Mr. Gunnar J. Malmin gave most effective help in further preparation of the *Scandinavian Guide*. Mr. Abel Doysié in Paris, Miss Ruth A. Fisher in London, and Miss Irene A. Wright in Seville, have aided the Department with their usual efficiency in all matters in which it has invoked their special knowledge of the archives of those cities.

The officials of the Library of Congress have, as in all previous years, constantly aided our work with the greatest liberality. Especial thanks are due to Dr. Herbert Putnam, librarian; to Dr. Charles Moore, chief of the Division of Manuscripts, and to Dr. John C. Fitzpatrick of that division; and to Lieut.-Col. Lawrence Martin of the Map Division. Grateful recognition is also made of the courtesy shown by the library of Harvard University in facilitating the work of Miss Donnan, and by the Virginia State Library and that of the Circuit Court of Appeals in Richmond in affording to Mrs. Catterall special opportunities for her work.

The present report being the last to be submitted by the present Director, it seems appropriate to present a brief survey of the work of the last twenty-three years, and thus to place the activities of the past year in intelligible relation to those of the years preceding.

The Department (originally called Bureau) of Historical Research was established by the Trustees of the Carnegie Institution in 1903, on the recommendation of its advisory committee for history, consisting of the late General Charles Francis Adams, Professor Andrew C. McLaughlin and J. F. Jameson. In 1905 it had been in operation for two years, under the conduct of Professor McLaughlin as Director. In that time it had established itself in the favor of historical scholars and in good relations with historical societies and other agencies for the advancement of historical work in the United States. It had produced the first edition of a much-needed *Guide to the Archives of the United States Government in Washington*, prepared by Messrs. C. H. Van Tyne and W. G. Leland. It had made a beginning of the collecting of letters in which members of the Continental Congress cast light on the secret proceedings of that body. It had set on foot three expeditions directed toward the acquiring of a fuller knowledge of the materials for American history in foreign archives, that of Professor C. M. Andrews to England, that of Professor W. R. Shepherd to Spain, and that of Mr. L. M. Pérez to Cuba.

From 1905 to 1928 the Department has been occupied with the systematic execution of a program formed in the first of these years, and fully set forth in the first of these annual reports. The definition then given of the proper functions of a department of historical research has been held securely in mind, without deviation, being based on principles deemed to be fundamental. Those principles were thus stated:¹

"The normal processes of historical work would commonly be said to be four: The finding of the original materials, printed or unprinted; the putting of them into accessible and well-edited print, if they have not already that

¹ Fifth Year Book, p. 186. They were more fully stated in a lecture given before the Trustees in November 1912, and printed in the *History Teacher's Magazine* for February 1913, under the title *The Future Uses of History*.

form; next, the production of monographs; and, finally, the composition of general histories. Unless under circumstances quite exceptional, the last two processes are better left to the free action of individual scholars. Given the materials, they will produce monographs and histories in the future, as they have in the past, and of a better flavor than those which might be turned out by an organized institution. In the main, it must be the proper function of an organized and permanent institution, disposing of ampler resources than most individual historians can command, to carry on the primary, fundamental, and costly tasks of finding the materials or guiding men to them, and of printing such of them as are unprinted and most deserve print, selecting those which are likely to give the greatest possible aid and incitement to the production of good monographs in important fields. For us at any rate, *melius est petere fontes quam sectari rivulos*.

"Accordingly, the publications of such a department will naturally fall into two classes: a series of reports, aids, and guides, mediating between the worker and his materials, printed or unprinted, and a series of texts; and the main business of this Department must be to plan, and so far as possible to execute, those publications, of these two sorts, which are most needed, or most likely to be of large utility, in the present state of American historical work."

By no means all of the program stated in that first report has been executed in these twenty-three years, for, as workers in history are well aware, it is in the nature of historical tasks to lengthen their dimensions beyond the limits which are foreseen at the beginning. But it is gratifying in the retrospect to see how much of it has been accomplished, through the steady labors of a staff that could hardly be surpassed in industry or devotion, or in competence for their specific tasks, aided at times by experts of high quality invoked from elsewhere.

One of the chief objectives in the Department's work, especially in the first half of the period surveyed, has been the making of a series of guides to the materials for American history in foreign archives. In these repositories vast masses of American material are preserved which it is quite impossible for the individual historian to subdue to his uses, till descriptive inventories covering whole collections have been systematically prepared and made available. Four volumes of such inventories of materials for American history in English archives have been published, two for those of Spain, and other volumes for those of Germany, Switzerland and Austria, Rome and other Italian capitals, Russia, Canada, Mexico, Cuba, and the British West Indies. To these add a second and enlarged edition of Van Tyne and Leland's *Guide*, already mentioned, a calendar of territorial papers in Washington, an inventory of materials for American religious history in Protestant church archives in the United States, a volume listing American manuscript materials in a large number of European libraries, and a calendar of documents in Paris archives relating to an important portion of American history, and we have a series of twenty volumes which, it may fairly be said, mark a substantial increase in the means for writing American history, over those which existed in 1905.

Fortunately, most of the program for this kind of work had been executed before the outbreak of the World War. That event, and the consequences

which it entailed, made such work considerably more difficult. Three portions of the program, not undertaken or completed before 1914, still lack something of their completion: the Guides to materials for American history in Dutch and Scandinavian archives, both of which are nearly finished, and that describing such materials in the archives and libraries of Paris, of whose three volumes one is finished and the others far advanced toward completion.

Another large task, completed a year ago, has been the preparation of an elaborate *Atlas of the Historical Geography of the United States*, intended for photolithographic reproduction, with a volume of letterpress.

Guides to materials for historical study and aids in their use have constituted one of the two chief divisions of the Department's work during these twenty-three years. The other has consisted in meeting another need of scholars by preparing volumes of documentary materials which would fill gaps existing in the published records for United States history, not filled or likely to be filled by federal or state agencies already in operation.

Such a program, not devised *in vacuo* but intended to supplement existing means for historical writing, naturally leads to a less rounded result than can be presented, for instance, in a series of reports on the American contents of European archives. If, however, what has been done is surveyed in its relation to the documentary sources for American history already in print, or in process of production by other agencies, there is ground for some legitimate satisfaction.

First, as to the colonial period. Of a series of volumes of *European Treaties bearing on the History of the United States and its Dependencies*, two volumes have been completed, a third nearly so. Two volumes of the *Proceedings and Debates of British Parliaments respecting North America* have been edited and published, a third approaches completion, and the texts for the remainder are mostly in hand. Two volumes of *Historical Documents relating to New Mexico, Nueva Vizcaya, etc.*, have been published, and of the remaining two the documentary texts are completed. The history of the Continental Congress, of which hitherto little has been known beyond what is presented in the bare Journals of its secret sessions, has been amplified to the utmost extent now possible by the publication of all relevant portions of the letters of its members—four volumes already published and texts for the remaining three assembled.

The middle period of our history has been illustrated by a six-volume edition of the *Correspondence of Andrew Jackson*, of which three volumes are already before the public. The history of American slavery as a social institution has been illustrated by the publication of a volume of judicial cases from the law reports. Another, and the larger part of a third, are ready. Other volumes, in an advanced state of preparation, document and illuminate the history of the slave trade.

Meanwhile, the Department has also served as a clearing-house for the historical profession, has aided the American Historical Association in various ways, and has answered innumerable inquiries, especially such as required for their answer the historical resources of Washington; and it is apparently thought by the profession that its editing of the *American*

Historical Review during these twenty-three years has been quite as useful to the maintenance and advancement of historical studies in the United States as the preparation and issue of the forty substantial volumes, printed or in the printer's hands, which have been briefly described in preceding paragraphs.

The work of the past year may most conveniently be described, according to the custom followed in previous reports, under the three headings: (1) Reports, Aids, and Guides; (2) Textual Publications of Documents; and (3) Miscellaneous Operations.

REPORTS, AIDS, AND GUIDES

The third volume of Mr. Leland's *Guide to the Manuscript Materials for American History in the Archives and Libraries of Paris* (Publication No. 392), reported a year ago as finished, was found to lack a few items toward entire completeness; these were supplied, and the manuscript was sent to the printer in May. It will make a volume of some 300 pages, and will make known to investigators, by itemized lists duly explained, several thousand manuscripts bearing on American (including Canadian) history in the Bibliothèque Nationale, and several hundreds in other Parisian libraries.

By the aid of Mr. Parker, much the larger part of volume I of the *Guide* above referred to has been made ready for the printer. This volume is chiefly concerned with those papers relating to the history of America, especially Canada, Louisiana and the Mississippi Valley, which have been preserved in the archives of the ministries of Marine and Colonies, or transferred thence to the Archives Nationales. Certain sections, whose contents have not yet been sufficiently explored, remain to be examined by Mr. Parker in Paris in the immediate future. Volume II of this series will be mainly devoted to the materials for American history to be found in the archives of the Ministry of Foreign Affairs. Mr. Leland's long labors there require to be supplemented, before the volume can be regarded as complete, by the exploitation of those volumes of Franco-American diplomacy from 1848 to, it is hoped, 1862, which a recent decree of the archive council of the ministry has thrown open to examination for historical purposes.

The second and completing volume of Mrs. Surrey's *Calendar of Manuscripts in Paris Archives and Libraries relating to the History of the Mississippi Valley*, covering the years from 1740 to 1803, has been completed by the planograph, with the exception of the index, which Mr. Matteson has begun to prepare; but the making of an index to a calendar listing at least 20,000 documents is, it will be understood, a laborious and time-consuming task.

On the *Guide to the Materials for American History in Dutch Archives* no work has been done during the year. It can not be finished until certain parts have been revised, at the Hague itself, because the original notes were taken so long ago. It is hoped that this revision can be effected in the summer of 1928.

The *Guide to Materials for American History in Scandinavian Archives* was advanced considerably nearer to completion in the summer of 1927, but was not completed. It may be remembered that the manuscript of the book was, from the circumstances of its origin, somewhat of a patchwork by various hands. Mr. Gunnar J. Malmin, who in 1923 did a part of the work of note-taking in Scandinavian archives toward the original preparation of this volume, returned to it in July and spent several very industrious weeks, with appropriate assistance from the Director, in reducing its various elements to uniformity and making out of it, to the extent possible, an orderly text. This process of assembling and arranging of the raw material, however, brought to light considerable gaps in the latter, specifically in the notes on materials in the archives of the Swedish Foreign Office concerning diplomatic relations between Sweden and the United States. The unfortunate death of Dr. Erik Naumann, of those archives, who had kindly undertaken to complete these notes, has thus far prevented the closing of this gap in the material for the volume. Another archivist has agreed to supply what is needed, a little later.

Dr. Paullin's *Atlas of the Historical Geography of the United States* was reported as finished, maps and letterpress, a year ago, and was transmitted to the administrative offices of the Institution. The Department has no further report to make respecting it, it being understood that, by reason of the increase in the costs of photolithographic work since the Atlas was begun, the Institution has not yet found practicable means for its publication.

TEXTUAL PUBLICATIONS OF DOCUMENTS

In June the Institution published the fourth volume of *Letters of Members of the Continental Congress* (Publication No. 299), edited by Dr. Burnett, and, like its predecessors in the series, provided by him with an illuminating preface, an elaborate series of data respecting the attendance of members, and all needed annotations. It is a volume of LXVI+551 pages, embracing the letters of 1779—letters or parts of letters, 703 in number, written by members of the Congress from the seat of its sessions and casting light on its transactions additional to what is to be obtained from the bare Journals. With Dr. Burnett's editing, these texts make a great addition to public knowledge of one whole year of the Revolution. The fifth volume, on which Dr. Burnett has been engaged during much of the year reported upon, covers the years 1780, 1781, and at least half of 1782. The manuscript is completed as far as the end of June 1780.

The third volume of Professor John S. Bassett's edition of the *Correspondence of Andrew Jackson* (Publication No. 371), embracing letters written by him and to him between the beginning of 1820 and the end of 1828, was published by the Institution in March. Its accomplished editor was brought on January 27 to the end of a most honorable and useful life, by a tragic accident in the streets of Washington. He had read all proofs of this volume with the exception of those of the preface, which were waiting in the office of the Department for his expected visit. His editorial work upon the remaining three volumes was long since completed. A mod-

erate amount of labor will make them entirely ready for the printer, but they must perforce lack the masterly prefaces which the biographer of Jackson, with his minute knowledge of the general's career and surroundings and his genial yet discriminating appreciation of Jackson's character, could alone supply. Provision for the publication of the fourth volume was made early in 1928, and its manuscript was sent to the printer in the last of the twelve months herewith reported upon. It includes letters written between the beginning of the year 1829 and the end of the year 1832, that is, from a time when Jackson was preparing to assume the presidency to a date soon after his second election—four years of great interest, nearly equivalent to those of his first term of office.

Miss Davenport, from the time of her return from her summer vacation, struggled valiantly in spite of failing health to finish the second and third volumes of her *European Treaties bearing on the History of the United States and its Dependencies*, and continued the effort with unabated ardor to the last day on which work was physically possible. The second volume, extending from 1649, just after the Westphalian treaties, to 1697 and the treaty of Ryswick, was complete in all substantial respects, at the time of her death, but had not received her final revision. It needed a multitude of small touches before it was wholly ready for the printer, and these the Director has supplied, together with more accurate texts of a few treaties of which photographs had been received after Miss Davenport ceased from her labors. There was no occasion to alter the well-considered narratives and conclusions set forth in the introductions which she had prefixed to the respective treaties, and which give to the work so large a part of its value.

The volume thus completed was sent to the printer at the beginning of June. It embraces forty-four treaties—introductions, texts, translations in cases where the treaty is not in English or French, and annotations. On the third volume some labor has been expended, by the Director and Dr. Paullin, who succeeds to the conduct of Miss Davenport's task, but it is still unfinished, partly from the lack of certain photographic texts which there has been difficulty and delay in procuring. It will contain twenty-six treaties, ranging from 1698 to 1715—from the next treaty having American bearings after that of Ryswick to the last of the treaties involved in, or corollary to, the great settlements at Utrecht. All but the last nine of these had been finished by Miss Davenport, except for the minutiae of typographical preparation. The volume will be of nearly the same size as the first and second, for the documents embraced in it, though fewer, are of greater average length.

Besides assisting in the perfecting of these volumes, Dr. Paullin has been engaged in the preparation of volume IV, continuing the series. For what remains of the series a different plan has been resolved upon, less elaborate than that followed by Miss Davenport, and admitting of more rapid progress toward the later periods of American history, especially toward the period of the wars of the French Revolution and the Napoleonic period. With that period, in which the European treaties are of maximum interest to students of United States history, the series is expected to end at 1815. Dr. Paullin's work has consisted thus far in selecting or discover-

ing the treaties which fall within the scope of the enterprise, selecting the relevant portions in the case of treaties only partly involved, and discovering the location of the most authoritative (ratified) texts. This process has been carried down from 1716 to 1780. The Director expects to obtain the photographic texts, necessary for complete accuracy, in Europe during the coming summer.

Mrs. Catterall's work during the year consisted in digesting and preparing for publication, from the law reports of North Carolina, South Carolina and Tennessee, the materials for the second volume of her *Judicial Cases concerning American Slavery and the Negro* (Publication No. 374). That volume was finished in March, and at the beginning of June was placed in the printer's hands. Like the preceding volume, it presents all significant items of social fact in a thousand cases concerning slavery, in the three states named, and sets forth succinctly but with great accuracy the opinions of the Carolina and Tennessee judges. Slavery and its incidents in a second tier of slave states are thus illustrated, copiously and with fidelity. It will perhaps be remembered that the work in several other states or jurisdictions has been completed, notably in Maryland, Delaware, the District of Columbia and Missouri, and Arkansas has been added during the past year; but it appears that these are not to be suitably combined in the same volume, and they will be postponed till after the Gulf states.

The third volume of the *Proceedings and Debates of the British Parliaments respecting North America* (Publication No. 338), edited by Dr. Stock, and intended to cover the reigns of Anne and George I, 1702-1727, approaches completion. The end of June has brought the editing to the end of the Fifth Parliament of Great Britain, in March 1722. There remains one more Parliament of five short sessions for the reign of George I, which will no doubt be finished by autumn.

Miss Donnan's work on the slave trade was advanced during the summer months by various dealings with eighteenth-century documents, and again suspended, as usual, when the academic year of Wellesley College began. Its completion waits for the sabbatical leave of absence which she will have during the academic year 1928-1929. Meanwhile we have an important by-product of her labors, in a substantial article on "The Slave Trade into South Carolina before the Revolution," appearing in the July number of the *American Historical Review*.

During the year Professor Hackett has completed the translations for the third volume of the *Bandelier Papers, Historical Documents relating to the History of New Mexico, Nueva Vizcaya, etc.* (Publication No. 330), but the unusual demand upon his time at the University of Texas has made it impossible for him to complete the editing of this volume, which he had hoped to do during the year now reported upon.

MISCELLANEOUS OPERATIONS

As heretofore, the editing of the *American Historical Review* has been carried on in the office of the Department and by its staff, mainly by the Director and Miss McKee, with the aid of Dr. Burnett in one section.

Various help has been given to the American Historical Association and other historical societies, especially in respect to investigations in Washington archives, and many questions raised by American historical scholars and other inquirers have been answered with such success as the familiarity of the staff with Washington resources permitted. In addition to the maintenance of such correspondence, the Director has served as chairman or member of various committees of the American Historical Association, as chairman of the Committee of Management of the *Dictionary of American Biography*, as one of the two representatives of the American Historical Association in the American Council of Learned Societies, and as chairman of a committee formed for a special purpose by the International Committee of Historical Sciences. Dr. Stock has, as usual, given courses of historical instruction in the Catholic University of America, and has borne a part in the editing of the *Historical Outlook*.

DEPARTMENT OF MERIDIAN ASTROMETRY ¹

BENJAMIN BOSS, DIRECTOR

Since publication of the last report of the Department of Meridian Astrometry the San Luis Catalogue has been printed. It contains the positions of 15,333 stars, mostly situated in the southern hemisphere; all the southern stars to the seventh magnitude, together with many fainter ones, are included. With the exception of the adoption of the equinox, the catalogue is fundamental. Its fundamental nature and comprehensive field fill a much felt want. Moreover, it represents the completion of the first step toward the fulfilment of a larger plan, the formation of a General Catalogue of positions and motions of over 30,000 stars from pole to pole.

The supplement to the San Luis Catalogue, the Albany Catalogue, including a similar list of stars principally located in the northern hemisphere, is well on its way toward completion and work on the General Catalogue is in progress.

REDUCTIONS OF OBSERVATIONS

ALBANY RIGHT ASCENSIONS

Since the last report, the preliminary places for computing precessions and secular variations have been formed for the remaining 10,000 cards. The precessions for 13,000 stars have been computed in duplicate and checked. Precessions have been entered upon the two sets of collection cards for the remaining 17,000 stars and the entries have been checked. The 17,000 remaining secular variations have been computed in duplicate, checked and entered upon the cards. With these checked values of the precessions and secular variations, the separate observations in right ascension have been reduced to 1910 and the mean right ascension for 1910 formed for the 20,775 cards. The separate reductions and the final means have been checked.

When the observations of each star were collected on the cards, it was found that uniformity of magnitude was not employed to reduce the transits for each star. If the correction for magnitude is to be employed, the same magnitude should be used for all observations of the same star except, naturally, where estimates have been made by the observers. This was not the case. To remedy this defect and also to provide reasonably correct magnitudes for publication, a complete revision of the magnitudes was made. The magnitudes of the Harvard Draper Catalogue were taken as standard and the revised magnitudes fall into four general classes.

(1) When the Harvard magnitude was given to two decimal places, this was adopted as the definitive magnitude. In the case of double stars, where the magnitude given is the combined magnitude of the two stars or that of the brighter only, the difference of magnitude as given in Burnham's *General Catalogue of Double Stars* was used to derive the magnitudes of the components.

¹ Address: Dudley Observatory, Albany, New York.

(2) When the Harvard magnitude was given to one decimal only, this was adopted if there were no Albany estimates of magnitude. When there were Albany estimates, the mean of these was combined with equal weight with the Harvard value.

(3) When the star was not found in the Harvard Catalogue but was found in the *Bonn Durchmusterung*, the Bonn magnitude was corrected by means of the Harvard tables and used in the cases where there were no Albany estimates of magnitude. Where there were Albany estimates, the two were combined with equal weight.

(4) For a few stars not found in either the Harvard or Bonn Catalogues the Albany estimates alone were used. In a few cases, also, where the Bonn magnitudes were apparently greatly in error, as evidenced by the Albany and A. G. Catalogue estimates, the Albany estimates alone were used.

With the final magnitudes thus derived, the places entered on the cards were corrected differentially for each observer for the differences between the adopted magnitude and that used in the reduction. No correction was applied to transits reduced with Albany estimates alone. These corrections were applied before the reduction to 1910.

The systematic errors which may have been introduced into the final magnitudes by employing the Albany estimates are shown in the accompanying table under ΔM . Here are given the number of estimates, mean ΔM , and probable error of an estimate for observers Roy, Varnum and All for each 0.1 of a magnitude from 7.0 to 10.9, inclusive. In addition to the estimates by Roy and Varnum, there were estimates by other observers as follows: Albrecht 131, B. Boss 38, Sanford 21, L. Boss 2 and Zimmer 1. These additional 193 estimates were included in deriving the ΔM for All. Under this heading are given the number of stars in each group, mean ΔM , probable error of ΔM , and the probable error of a single estimate. At the foot of the table are given the mean values for each full magnitude and those for the whole range of the four magnitudes covered by the table.

The column ΔM of "All" contains the systematic errors of the Albany estimates which were not allowed for in deriving the final magnitudes. In the cases, therefore, where the mean of the Harvard or Bonn corrected magnitudes and the Albany estimates was taken, the final magnitude contains a half of the ΔM of All. In the few cases where the Albany estimates alone were used, the final magnitude may be in error by the full amount of ΔM . All seven observers estimated the stars with Bonn magnitudes fainter than 9.9 as much brighter, probably due to the fact that these stars were observed only on the best nights. Considering the fact that the observers were not engaged in determining the magnitudes of the stars and in the majority of cases estimated only to the nearest 0.5 of a magnitude, the values of ΔM indicate that they had a very close idea of the Harvard scale.

Albany Estimates of Magnitude Minus Harvard Draper Magnitudes

Roy				Varnum			All			
HD Mag.	No. Est.	ΔM	p.e.	No. Est.	ΔM	p.e.	No. Stars	ΔM	p.e. Diff.	p.e. Est.
M	M	M	M	M	M	M	M	M	M	M
7.0	32	+0.14	± 0.13	8	+0.26	± 0.18	39	+0.18	± 0.20	± 0.14
.1	37	+ .14	.12	12	+ .17	.14	44	+ .16	.18	.13
.2	34	+ .11	.11	10	+ .17	.22	42	+ .14	.18	.13
.3	25	+ .03	.14	13	- .05	.14	35	+ .01	.20	.14
.4	46	- .05	.12	24	- .01	.13	62	- .03	.18	.13
.5	35	- .14	.13	15	+ .08	.20	44	- .07	.19	.13
.6	45	- .14	.17	23	+ .06	.24	67	- .08	.25	.18
.7	53	- .28	.21	18	- .18	.24	60	- .25	.27	.19
.8	56	- .19	.22	48	+ .02	.19	87	- .14	.29	.20
.9	73	- .36	.28	48	- .07	.24	100	- .23	.36	.25
8.0	70	- .33	.27	37	+ .00	.17	90	- .23	.33	.23
.1	64	- .34	.27	41	- .18	.25	93	- .29	.37	.26
.2	48	- .19	.28	39	+ .06	.19	77	- .12	.32	.23
.3	45	- .22	.23	37	+ .01	.24	77	- .12	.30	.21
.4	39	- .01	.26	43	- .07	.16	67	- .06	.28	.20
.5	58	- .02	.29	70	+ .02	.15	100	+ .01	.30	.21
.6	45	- .05	.28	63	- .01	.17	97	- .06	.27	.19
.7	49	+ .01	.26	60	- .05	.18	85	- .03	.28	.20
.8	44	+ .16	.25	61	- .02	.21	82	+ .02	.31	.22
.9	45	+ .15	.26	58	+ .04	.23	77	+ .06	.32	.23
9.0	42	+ .28	.25	37	+ .14	.22	60	+ .13	.25	.18
.1	43	+ .19	.19	45	+ .03	.22	71	+ .08	.25	.18
.2	71	+ .13	.21	49	- .07	.18	88	+ .07	.25	.18
.3	56	+ .13	.16	52	+ .01	.19	80	+ .05	.22	.16
.4	44	+ .16	.21	44	- .19	.25	65	- .09	.29	.21
.5	37	+ .11	.19	31	- .18	.17	47	- .06	.22	.15
.6	42	- .03	.16	37	- .22	.18	53	- .11	.21	.15
.7	42	- .06	.16	25	- .30	.23	45	- .17	.25	.18
.8	28	- .14	.20	18	- .18	.14	34	- .20	.26	.18
.9	25	+ .07	.09	10	- .23	.20	21	- .09	.16	.11
10.0	16	- .19	.12	7	- .39	.24	16	- .25	.24	.17
.1	11	- .21	.21	6	- .38	.31	11	- .33	.31	.22
.2	11	- .22	.28	6	- .20	.34	10	- .17	.36	.25
.3	6	- .43	.27	2	- .30		4	- .44		
.4	6	- .53	.34	2	- .65		4	- .51		
.5	1	-1.00		4	- .62		3	- .50		
.6	2	- .90					1	- .90		
.7	1	+ .30					2	- .30		
.8	-----	-----					-----	-----		
.9	2	- .40					1	- .40		
M	M	M	M	M	M	M	M	M	M	M
7.5	436	-0.12	± 0.18	219	+0.01	± 0.20	580	-0.07	± 0.25	± 0.18
8.5	507	- .01	.27	509	- .02	.19	845	- .08	.31	.22
9.5	430	+ .10	.18	348	- .09	.20	564	- .01	.24	.17
10.5	56	- .29	.24	27	- .39	.30	52	- .32	.33	.24
M	M	M	M	M	M	M	M	M	M	M
7-11	1429	-0.05	± 0.26	1103	-0.04	± 0.20	2041	-0.07	± 0.27	± 0.19

ALBANY DECLINATIONS

The derivation of the corrections necessary to reduce the observations of each observer, in each position of the instrument, to a homogeneous system that will be as nearly as possible the undistorted mean of all has been completed and the corrections have been applied. The revision makes a notable improvement in the extension of the system south of the zenith, although the changes from the zenith to the pole were almost negligible. Corrections to the observations of Raymond, Sanford and Zimmer to reduce them to the Albany system, which is the weighted mean of the observations of Albrecht, Boss, Roy and Varnum, have likewise been derived and applied. The reductions to the equinox 1910.0 and the scrutiny of the individual results are well in hand.

With the derivation of the final personal corrections, a consideration of further adjustment of the preliminary Albany system was possible. As a first essential, a careful discussion was made of the variation with the zenith distance of the weight per observation. With $\pm 0'.30$ as the probable error of the unit of weight, the weight per observation for moderate zenith distances was found to be slightly more than unity and the decrease with increasing zenith distance was well represented by a uniform change from unity at declination $+95^\circ$ to zero at $+126^\circ$, a decided change from the preliminary weights.

With the differences, Upper *minus* Lower, arranged in order of polar distance, four solutions were made for a correction to the latitude in combination with a term varying with the tangent of the zenith distance, with the following results:

Declination limit	2Δ	Tangent term	Z.D. limit
65°50'	— 0".238	+ 0".1252	71°5
62 12	— 0.073	+ 0.0540	75.1
58 0	+ 0.161	— 0.0431	79.2
54 12	+ 0.204	— 0.0597	83.0

These results, highly sensitive to changes of weights, made it imperative to consider terms dependent upon the third and fifth powers of $\tan z$ and, with the introduction of these higher terms, the sensitiveness to changes of weights was nearly eliminated.

The preliminary Albany system was formed by a discussion of the circumpolar results as obtained with the Pulkova refractions, whence, with a correction of $+0.0952 \tan z$, z being the zenith distance north, a mean latitude of $+42^\circ 39' 12''.832$ was found. Introducing the higher powers of $\tan z$ into the discussion of the refined results, the following corrections are derived:

$$\begin{aligned} \Delta\delta &= -0''.032 + 0''.0585 \tan z - 0''.00318 \tan^3 z, & \text{or} \\ \Delta\delta &= -0''.368 + 0''.3755 \tan z - 0''.01915 \tan^3 z + 0''.000266 \tan^5 z. \end{aligned}$$

While the use of a term in $\tan^5 z$ makes a slight improvement in the circumpolar comparison, it introduces an intolerable result in the system south

of the zenith. Inasmuch as in the solutions, seven-tenths of the coefficient of this term are derived from less than 100 observations at zenith distances exceeding $80^{\circ}25'$, its existence can not be considered as demonstrated and it has, therefore, been rejected. The correction derived without it has been adopted and applied as here tabulated.

Corrections to Preliminary Albany System

Decl.	$\Delta\delta$	Decl.	$\Delta\delta$
+124°	-0.55	+30°	-0.04
+120	-0.05	0	-0.08
+110	+0.07	-20	-0.12
+90	+0.03	-36	+0.06
+60	-0.01	-39	+0.54

The results of a comparison of the Albany system, corrected for the term in $\tan^2 z$, with the system of the *Preliminary General Catalogue* are shown in the following table:

Comparison of Albany and P. G. C. Systems

Decl.	wt.	U — L	Decl.	wt.	Decl.	wt.
+56° S.P. 14	+0.36	-0.27	+68° 192	-0.04	+12° 235	+0.59
+60 S.P. 41	-0.09	+0.17	+64 214	-0.04	+8 348	+0.46
+64 S.P. 69	+0.02	-0.06	+60 210	+0.08	+4 327	+0.58
+68 S.P. 83	+0.02	-0.06	+56 230	+0.09	0 217	+0.50
+72 S.P. 84	+0.19	-0.12	+52 153	+0.23	-4 247	+0.52
+76 S.P. 99	0.00	-0.05	+48 191	+0.34	-8 302	+0.52
+80 S.P. 86	-0.06	+0.04	+44 148	+0.44	-12 194	+0.43
+84 S.P. 114	-0.01	+0.07	+40 283	+0.36	-16 265	+0.54
+88 S.P. 136	+0.04	-0.01	+36 122	+0.34	-20 164	+0.54
+88 132	+0.03		+32 166	+0.39	-24 274	+0.55
+84 117	+0.06		+28 290	+0.45	-28 164	+0.55
+80 108	-0.02		+24 230	+0.55	-32 96	+0.54
+76 180	-0.05		+20 300	+0.65	-36 68	+0.55
+72 174	+0.07		+16 282	+0.59	-39 8	+0.74

These differences are in substantial accord with the corrections to the system of the *Preliminary General Catalogue* indicated from other sources.

MISCELLANEOUS INVESTIGATIONS

INVESTIGATION OF CLOCK CORRECTIONS

The evidence in favor of a varying rate of rotation of the Earth has suggested the possibility of tracing some of the shorter period changes through a careful scrutiny of the clock corrections. The problem is a delicate one because other elements are involved, such as mechanical changes, personality of the observers and unknown meteorological effects. The investigation has not progressed sufficiently to arrive at definitive results, but it can be stated that there is evidence that the personal errors of the observers change rather smoothly over the period investigated. The variation of the clock correction undergoes curious changes which evidence little if any connection with meteorological conditions. For the present it has been assumed that these changes are due to mechanical sources and that they vary smoothly.

Residual deviations may then be attributed to other causes. Examination of the resulting deviations bears evidence of periodicity, but further investigation must be undertaken before it is advisable to place much reliance upon the results. Interpretation of the variations must, therefore, await further developments.

STELLAR MOTIONS

Wilson and Raymond have completed the computations of the coordinates of the space motions of over 4,200 stars, for which proper-motions, radial velocities and parallaxes are available. These data are being analyzed for the determination of solar motion, preferential stellar motion, group motions and related problems. In the accompanying tables Wilson exhibits some of the results already obtained for solar and preferential motion.

Solar Motion

Velocity Groups									
V	A ₀	D ₀	V ₀	**	V	A ₀	D ₀	V ₀	**
km.			km.					km.	
0- 10	276.8	+29.6	18.8	457	< 30	271.4	+25.0	16.4	2576
10- 20	273.1	24.9	17.8	1142	< 45	271.3	28.0	15.8	3326
20- 30	265.5	22.1	13.8	977	< 60	272.4	29.2	16.6	3640
30- 45	270.9	39.8	14.4	750	< 80	274.0	30.3	17.3	3868
45- 60	281.5	38.3	24.8	314	< 100	274.4	30.9	18.0	3968
60-100	287.7	39.3	38.1	328	< 150	274.8	30.9	17.8	4073
>100	300.4	42.1	107.6	152	All	276.0	31.9	19.0	4120
>150	306.1	47.3	189.0	52					
Type Groups									
B	276.6	+29.7	18.5	475	13.5 ¹				
A	269.4	27.4	14.7	868	17.5				
F	269.5	26.7	17.9	577	25.4				
Gg	270.3	30.9	15.7	323	22.4				
Kg	276.7	35.6	17.5	876	27.6				
Mg	282.4	39.4	19.5	346	27.5				
Gd	284.6	31.3	35.0	333	51.9				
KMd	283.2	36.1	35.0	159	59.5				

¹ Median stellar velocity.

Preferential Motion

Velocity Groups									
V	A ₁	D ₁	σ ₁	A ₂	D ₂	σ ₂	A ₃	D ₃	σ ₃
km.			km.			km.			km.
0- 10	116.9	-21.8	4.3	61.0	+53.7	4.3	195.2	+26.5	3.7
10- 20	101.7	- 4.1	9.5	18.5	60.1	9.1	189.4	29.5	7.2
20- 30	92.9	+ 8.5	17.8	346.6	61.6	12.3	187.3	26.9	10.8
30- 45	94.9	14.2	26.8	331.5	65.4	17.9	190.1	19.6	15.4
45- 60	89.4	20.7	38.5	314.4	61.7	26.2	186.3	18.2	21.3
60-100	90.4	22.7	58.6	312.5	55.8	33.5	188.0	17.5	28.0
>100	87.4	34.0	122.0	315.9	44.4	93.7	196.9	26.3	59.2
< 60	93.1	+13.9	19.7	333.1	+63.6	14.3	188.8	+22.0	11.7
< 100	92.6	16.2	24.5	327.5	63.3	17.2	188.7	20.4	13.4
All	94.5	14.3	28.2	335.4	62.2	21.7	190.8	23.2	15.0

These results show that both the direction and amount of the solar motion are simple functions of the stars used in the determination, that both increase simultaneously with increase in the velocities of the stars used. They further indicate that the apex of preferential motion rotates in a clockwise direction around the Galaxy with increase in the velocities of the stars. It follows that any determination of solar or preferential stellar motions must be directly dependent upon the limits of rejection, even though the larger values of the velocity coordinates be given reduced rates upon the basis of their relative frequencies. In other words, the so-called skew motion of the stars is not confined to the stars of the so-called high-velocity groups, but continues into the velocity distribution of the stars of more moderate speeds. The low values of the declination of the solar apex for stars of velocities 15 to 30 km./sec. is due primarily to the enlarged Taurus stream, composed of stars moving in the general direction with the well-known Taurus cluster. The low solar speed indicated by the stars with velocities 20 to 45 km./sec. is primarily due to the enlarged Ursa Major Stream, which moves in the general direction of the solar motion, but with a much greater speed, thus tending to indicate a solar motion in the opposite direction to that indicated by the stars in general.

The values of the apices of both solar and preferential motion as derived from stars of different spectral types are shown to be directly related to the average speeds of the stars in these classes. Values of the solar speed derived from the early type stars and the later type giants are accordant, while those derived from the late type dwarfs are definitely greater, as would be expected in view of their much greater average speeds. Values of the right ascension and declination of the solar apex derived from the latest type stars, Classes K and M, are definitely greater, both for giants and dwarfs, than those derived from stars of the earlier classes. In the determination of the directions of solar and preferential motions from the stars as a whole, limitation of the data makes relatively little difference if the stellar velocity coordinates are weighted in accordance with their relative frequencies, but the solar speed and the amounts of motion along the axes of the velocity increase directly with the speeds of the stars involved, no matter what the system of weighting may be.

Raymond has examined the more general characteristics of the velocity distribution depending upon the moments of the first, second and third orders. From 4,192 stars, for which the data were considered reliable, each star being given unit weight, including the individual stars of such groups as Taurus and Ursa Major, he finds for the solar motion:

$$A \ 278^{\circ}.4 \quad D \ +33^{\circ}.2 \quad V_0 \ 21.41 \text{ km.}$$

These values are all large, as is always the case when stars of large velocity are included.

The second order moments give for the three principal axes of distribution of velocities:

		km.
$A_1 \ 96^{\circ}.6$	$D_1 \ + \ 9^{\circ}.2$	$\sigma_1 \ 35.2$
$A_2 \ 344.9$	$D_2 \ +66.3$	$\sigma_2 \ 29.7$
$A_3 \ 190.3$	$D_3 \ +21.7$	$\sigma_3 \ 18.2$

σ is the dispersion in the given direction. The dispersions in the three directions of the coordinate axes are σ_x 20.7 σ_y 34.8 σ_z 28.6. The pole of avoidance lies near the pole of the Milky Way ($190^\circ 3$, $+27^\circ 4$). The declination of the pole of preference seems rather low for stars, so many of which have high speeds. Its galactic latitude is only 1° .

The skewness, β_s , is defined by Charlier as minus the mean cube divided by six times the cube of the dispersion, that is
$$\beta_s = - \frac{\bar{\xi}^3}{6\sigma^3}$$

The values of this quantity in the three coordinate directions are, respectively, $+0.390$, -0.430 and $+0.816$, all large values. The maximum skewness is $+0.905$ toward the point ($334^\circ 5$, $+66^\circ$), and the minimum, of course, toward the antipodal point. The direction in which the mean cube component is a minimum is not the same as this, but is directed toward (299° , $+30^\circ$). The direction of maximum skewness is in the galaxy and nearly 90° from the supposed center of galactic system in *Sagittarius*. This suggests that the skewness may be the result of rotation in the galactic plane unequally distributed between the two directions. Further investigation is in progress.

STELLAR WAVE-LENGTHS

A new Gaertner spectrocomparator purchased with funds obtained from the Rumford Committee of the American Academy of Arts and Sciences was tested by Albrecht. The maximum periodic error of the screw was found to be 0.0005 mm. and the maximum progressive error is only 0.001 mm. This is very satisfactory and in keeping with the high quality of the instrument in other respects.

An investigation by Albrecht of the spectrum of γ *Geminorum*, of Class A0, has been carried out. For this purpose spectrograms taken at the Yerkes Observatory with three-prism dispersion were measured with the Gaertner spectrocomparator, using a daylight lamp as a constant source of illumination. Wave-lengths were determined for 233 lines between 4283A and 4704A. 98 of these were identified with lines of ionized metals, best represented among which are: titanium 31, iron 25, zirconium 12, and chromium 9 lines. $H\gamma$ is strong, while the lines of helium seem to be absent. Some unenhanced lines, principally of iron and titanium, are also present.

Reduction tables on the international system for three-prison spectrograms have been extended to include over 500 lines.

STAFF

The director has continued his investigations of phenomena connected with the variable rotation of the Earth. Ralph E. Wilson has been engaged in investigations of stellar motions, has continued to act as Secretary of the Department and assisted in the publication of the *Astronomical Journal*. Harry Raymond has been engaged in the investigations of stellar motions.

Arthur J. Roy has been in charge of the reductions of the Albany declinations and of the work upon the General Catalogue of proper motions. William B. Varnum has continued in charge of the reductions of the Albany right ascensions. Sebastian Albrecht has continued his investigations of stellar wave-lengths. Heroy Jenkins and Sherwood B. Grant have assisted Mr. Roy with the work on declinations and the General Catalogue. Miss Isabella Lange has continued to supervise the reductions in right ascension under the direction of Mr. Varnum.

The Misses Grace I. Buffum, Lillian F. Blanchard, Marie Lange, Frances L. McNeill, Edith W. Davies, Charlotte Simmons and Helen M. Hoffman, together with a number of piecework computers, have constituted the computational staff.

MOUNT WILSON OBSERVATORY

GEORGE E. HALE, HONORARY DIRECTOR

WALTER S. ADAMS, DIRECTOR

FREDERICK H. SEARES, ASSISTANT DIRECTOR

The completion of two extensive and important investigations which have been in progress during a considerable portion of the life of the Observatory has been one of the most noteworthy results of the past year. The first of these is the *Revision of Rowland's Table of Solar Spectrum Wave-lengths* by Mr. St. John, assisted by several members of the Staff. With the publication of this valuable collection of material the astronomer or physicist will have at his command an accurate system of wave-lengths for about 22,000 lines in the solar spectrum, together with a great amount of data relating to the classification of these lines according to temperature, pressure, and excitation and ionization potentials, which recent advances in physical theory have made possible. The *Revised Table* also includes an extension of *Rowland's Table* to longer wave-lengths, a comparison of the intensities of lines in sun and sun-spots, and a complete revision of all identifications, which has added very greatly to the number of lines of elements recognized as present in the sun. In the course of this work the presence of six elements not known previously in the sun's atmosphere has been satisfactorily established.

The second investigation is the *Mount Wilson Catalogue of Stars in the Selected Areas*, now completed under the direction of Mr. Seares. This brings to a close a series of related investigations which began in 1909. The catalogue includes measures of brightness of about 68,000 faint stars in sample regions distributed uniformly over the sky. The resulting magnitudes serve the two-fold purpose of providing standards for the measurement of the brightness of stars in neighboring regions, and material for a new discussion of the distribution of stars. This discussion, which bears directly on the structure of our system of stars and the position of the sun within it, has also been completed.

The Observatory has continued its cooperation with other departments of the Institution in the study of certain special problems. Among these reference may be made to the investigation of solar activity as related to magnetic storms, in which the Department of Terrestrial Magnetism is vitally interested; and to the study of the surface features of the moon carried on in cooperation with the staff of the Geophysical Laboratory. The Observatory has also assisted in the design and construction of the spectroscopic apparatus planned by Dr. Day for the study of the spectra of volcanic flames.

An interesting illustration of the value of the close relationship of the staff of the Observatory to that of the California Institute in the consideration of physical problems has been afforded by the recent identification of the principal unknown lines in the spectra of gaseous nebulae by Dr. Bowen of the California Institute. This has been one of the celebrated problems of

physical astronomy, and was brought to his attention through discussions with members of the Observatory staff. His identification of these lines as arising from transitions within atoms of oxygen and nitrogen, of rare occurrence under ordinary conditions in the laboratory, but very frequent at the low densities of the nebulae, is not only of great importance in itself, but also provides a valuable means for studying unknown lines and interpreting physical conditions in stellar atmospheres. The method has already been applied by Mr. Merrill to the identification with "forbidden" lines of ionized iron of a considerable number of previously unknown lines in the spectra of several important classes of stars.

STAFF

Dr. George E. Hale, Honorary Director of the Observatory, has continued his observations of the sun with the spectrohelioscope, making a special study of different types of solar disturbances. During recent months he has given much time to plans connected with the 200-inch telescope. Dr. Walter S. Adams, Director, has carried on the administrative work of the Observatory and has continued his investigations in stellar spectroscopy. Professor Frederick H. Seares, Assistant Director, has shared in the administration of the Observatory, and has completed and analyzed the results of his photometric observations of the stars in the Selected Areas.

Dr. John A. Anderson has devoted much of his time to studies of the spectra of metals and gases under conditions of exceptionally powerful excitation in the physical laboratory, and has continued his supervision of the ruling machine. Dr. Arthur S. King, Superintendent of the Physical Laboratory, has completed the investigation of the spectra of several of the rare earths in a variety of laboratory light-sources. Dr. Charles E. St. John has finished the *Revision of Rowland's Table of Solar Spectrum Wave-lengths*, and has continued his investigations of the solar rotation and the displacements and intensities of solar spectrum lines. Mr. Harold D. Babcock has been engaged chiefly in a study of the infra-red solar spectrum beyond the limits observed previously. Dr. Paul W. Merrill has continued his investigations of the spectra of red stars and of early-type stars with bright lines, and has been successful in the identification of many unknown lines. Dr. Edwin Hubble has made further progress in his researches on the distances and dimensions of spiral nebulae. Professor Alfred H. Joy, Secretary of the Observatory, has devoted his time to studies of the spectra of variable stars. Dr. Seth B. Nicholson has remained in charge of the solar observations, giving especial attention to problems connected with sun-spot polarities and solar activity. Dr. Francis G. Pease has continued observations with the 20-foot interferometer, and has given much time to the design of large telescopes as well as of auxiliary instruments. Dr. Edison Pettit has been engaged particularly in measurements of the ultra-violet radiation of the sun and related investigations, and in conjunction with Dr. Nicholson has completed the reductions of the measures of stellar radiation made during recent years. Dr. Adriaan van Maanen has continued his photographic determinations of stellar parallaxes and proper motions. Dr. Roscoe F.

Sanford has made a special study of a number of interesting spectroscopic binaries and has determined several orbits. Dr. Gustaf Strömberg has been engaged in computations of stellar motions and mean absolute magnitudes, and has aided in the stellar spectroscopic observations. Mr. Ferdinand Ellerman has continued his solar observations and has carried on much of the more important photographic work of the Observatory. Mr. Milton Humason has extended his work on the classification of faint stars in the Selected Areas, and has made many direct photographs and spectroscopic observations with the large reflectors. Dr. Sinclair Smith has made a study of the spectra of various gases, including oxygen and nitrogen, under a great variety of types of discharge in the laboratory, and has also been engaged in devising a new type of oscillograph. Mr. Lewis H. Humason carried on solar observations on Mount Wilson until the date of his resignation on January 1. This work has since been continued by Mr. Robert S. Richardson.

In the Computing Division Mr. Richardson and Mr. True Robinson have made measurements of sun-spot areas and positions, and have collected and classified sun-spot polarities. Mr. Edward F. Adams has measured the wave-lengths of solar spectrum lines and has compiled much of the material for the *Revised Table*. Miss Louise Ware has given most of her time to work with the registering microphotometer with especial reference to the measurement of the general magnetic field of the sun. Miss Charlotte E. Moore has devoted all of her time to the identification, and the analysis and classification according to energy level, of spectral lines included in the *Revised Table*. Much of this work finds wide application to other spectroscopic investigations. Miss Mary C. Joyner has continued to assist in photometric investigations and in the compilation of the *Mount Wilson Catalogue of Stars in the Selected Areas*. Miss Myrtle L. Richmond has carried on the measurement and reduction of the curves obtained in the observations of stellar energy. Mrs. Hannah M. Marsh has continued the measurement of stellar parallaxes and proper motions. Miss Cora G. Burwell, Miss Ada M. Brayton, Mrs. Katherine Kaster, Miss Elizabeth MacCormack and Miss Marguerite Wiberg have been engaged in stellar spectroscopic investigations, including the measurement of radial velocities, studies of individual spectra and many computations relating to stellar motions and absolute magnitude. Miss Wiberg resigned from the Computing Division on December 1. Mr. Wendell P. Hoge has assisted Mr. Babcock in his laboratory observations and in the measurement of infra-red spectra. He has also visited Mount Wilson on Friday evenings throughout the year, giving lectures and serving as curator at the 60-inch telescope on these occasions when it is available for public use. Miss Elizabeth Connor has continued her work as librarian of the Observatory, and has assisted Professor Seares in the editorial work involved in the publications.

Dr. A. A. Michelson, Research Associate of the Institution, spent a portion of the autumn months of 1927 in Pasadena and on Mount Wilson, and continued his investigations on the velocity of light and a possible drift of the ether. Dr. Henry Norris Russell, Research Associate, spent the months

of March and April in Pasadena. In addition to further studies on the analysis of complex spectra, Dr. Russell applied modern physical theories of line-intensities to solar and stellar spectra with most interesting results. As in previous years, the advice and suggestive criticism on problems of cosmogony given by Sir James Jeans, our third Research Associate, has been of great value to the members of the staff.

Dr. Fred. E. Wright, of the Geophysical Laboratory of the Carnegie Institution, Chairman of the Committee on the Physical Features of the Moon, spent the month of September 1927 in Pasadena and on Mount Wilson, and was engaged in organizing the work of the Committee and carrying on observations of the moon with the 60-inch reflector. Dr. Frank E. Ross, of the Yerkes Observatory, continued his photographic observations of the planet Venus in ultra-violet light during July 1927. Dr. Theodore Dunham, Jr., National Research Fellow, has been at the Observatory since September 1927. He has taken part in the regular stellar spectroscopic observations and has completed a detailed study of the spectrum of α Persei obtained with very high dispersion. Dr. Nicolas Perrakis, of the Observatory at Athens, has spent most of the year at the Observatory engaged in solar investigations. Dr. H. E. White, National Research Fellow at the California Institute of Technology, has carried on studies of the spectra of one or two of the rare earths from photographs obtained in the physical laboratory and at Mount Wilson.

Among the many visitors to the Observatory during the year there was none whose stay was appreciated more greatly than that of Dr. E. W. Brown, who spent two of the winter months in Pasadena.

SUMMARY OF THE YEAR'S WORK

The maximum of the present cycle of solar activity seems to have been reached during the first half of the year 1927. The remainder of the year showed a marked decrease, followed early in 1928 by an increase which did not, however, reach the high level of the preceding year. The abundance of sun-spots has made it possible to obtain extensive data on polarities and to carry on investigations on the relationship of spot activity to terrestrial magnetic storms. The spectra of sun-spots have been photographed in the near infra-red to a limit much beyond that reached previously. Observations of solar disturbances and fields of force in the sun's atmosphere have been carried on regularly by Hale with the spectrohelioscope, and most valuable results have been obtained from measurements of the radial velocities of the dark and bright prominences rendered visible with this instrument. New and important improvements of the spectrohelioscope have been made as a result of further experience in its use.

A total of 424 groups of sun-spots was observed on 312 days during the calendar year 1927 by Nicholson, Ellerman, L. H. Humason and Richardson. The polarities were determined for 405 individual groups, of which 394 proved to be regular, and only 11, or less than 3 per cent, irregular in the sign of their magnetic fields. The average latitude of the spots decreased during the year, thus affording additional evidence that the maximum is probably past.

Nicholson has made a special study of the intense terrestrial magnetic disturbances of May and June 1928. These were found, in general, to accompany large, active and complex spot groups around which the hydrogen flocculi showed great activity.

The *Revision of Rowland's Table of Solar Spectrum Wave-lengths* has been completed and made ready for publication by St. John and his associates. In addition to the wave-lengths, upon the International System, of nearly 22,000 lines, the table contains a great number of new and revised identifications, and a very large amount of physical data relating to the temperature and pressure classification of the lines, their energy-levels and multiplet relationships. The presence of six elements not known previously in the sun's atmosphere has been established in the course of this work.

The extension of the *Revision of Rowland's Table* toward longer wave-lengths has been made possible by Babcock's investigation of the infra-red solar spectrum beyond the region previously photographed. The use of improved photographic plates and apparatus has enabled him to obtain negatives showing the principal lines as far as $\lambda 11900$. Over 600 new lines have been measured, among them the prominent line of the Ritz-Paschen series of hydrogen at $\lambda 10049$.

A calibration of the intensities of solar lines given in *Rowland's Table* has been carried out by Russell, Adams and Miss Moore, based on formulæ for the relative intensities of multiplets derived from the correspondence principle. The resulting formula gives a relationship between the relative numbers of atoms active in producing a line and the Rowland intensity, and may be applied to stellar spectra for which the Rowland scale has been used.

The continuation of St. John's investigation of the gravitational displacement of solar lines has given further evidence of the agreement of observation with the relativity theory. Lines of medium level in the solar atmosphere show the displacement in exactly the predicted amount, while those of higher level show somewhat more, and those of lower level somewhat less, than the theoretical value. A study of these lines at the sun's limb indicates that the deviations from theory are very probably to be ascribed to convection currents, directed upward at low levels and downward at high levels in the solar atmosphere.

Pettit has continued his observations of ultra-violet solar radiation at $\lambda 0.32\mu$, with results which show a marked parallelism with the curve of sun-spot group numbers. It is evident, therefore, that the principal changes in light of the sun as a variable star are in the ultra-violet. In the course of this investigation Pettit has also measured the ultra-violet radiation of the sky under various conditions of clearness. The amount of such radiation is found to be surprisingly large, even on completely cloudy days.

Direct photography of the moon has been limited for the most part to observations made in ultra-violet ($\lambda 0.32\mu$) and near infra-red ($\lambda 0.7\mu$) light. Photographs taken in this way by Pettit show a few areas which are relatively much darker in ultra-violet light.

Dr. Ross, of the Yerkes Observatory, completed during July 1927 a series of photographs of the planet Venus in light of different colors. Dark and

bright areas were found on the ultra-violet photographs which were faint in blue light and did not appear at all in infra-red light. The bright areas are usually near the cusps, and the dark areas are usually seen as bands near the equator. From his results Dr. Ross concludes that the rotation period is less than the orbital period, and that the diameter in ultra-violet light is about 2 per cent greater than in red light. The outer atmosphere of Venus Dr. Ross considers to be composed of a thin stratum of cirrus clouds, billowy in character, while the inner atmosphere is exceedingly dense and yellowish in color.

Hubble has continued his general survey of faint nebulae with the large reflectors and has completed his study of stars in the Andromeda nebula. From the Cepheid variables he finds a distance for the Andromeda nebula about 5 per cent greater than for Messier 33. The 86 novæ observed in the Andromeda nebula indicate a frequency of between 25 and 30 a year, and their light-curves at maximum show a restricted range of 3 or 4 magnitudes. The maximum frequency occurs at photographic magnitude 16.5, or absolute magnitude -5.7 , at the distance indicated by the Cepheid variables.

From counts of faint nebulae made on long-exposure photographs Hubble finds a correlation between exposure time and numbers of nebulae, the numbers increasing at approximately the theoretical rate for uniform distribution in depth. The assumption that the distribution over the sky in high galactic latitudes is approximately uniform is involved in this result. About 170 nebulae per square degree are found on negatives taken with the 100-inch reflector with an exposure time of 2 hours.

Nebular spectroscopy during the year has included the determination of a radial velocity of -130 km./sec. by Humason for N.G.C. 6822 from measurements of emission lines; and a velocity of -300 km./sec. and a spectral type of F5n, for N.G.C. 205, the fainter companion of the Andromeda nebula. Merrill has used the plane-grating spectrograph to obtain photographs of the nebular lines to the red of $\lambda 7100$, and his detection of the double character of $\lambda 7325$ adds confirmation to Bowen's identification of it as a forbidden line of ionized oxygen.

With the completion of 250 measurements of trigonometric parallax, van Maanen has made a study of the probable errors of the determinations. He finds a value of $\pm 0''.006$ for the parallaxes obtained at the Cassegrain focus of the 60-inch reflector, and $\pm 0''.010$ for those at the primary focus of the 100-inch. These values are confirmed by a comparison with a list of stars for which theoretical values of the parallax can be derived. Another investigation by van Maanen has dealt with the systematic errors of the series of trigonometric parallaxes published by different observatories. He concludes that systematic errors which depend on right ascension are present in all the series, and derives the corrections necessary to eliminate this effect.

In the field of stellar photometry the completion of the great catalogue of photographic magnitudes of the stars in the Selected Areas is a notable event. Carried on by Seares, with the assistance of Miss Joyner and Miss Richmond, and in cooperation with the Kapteyn Laboratory at Groningen,

this investigation has involved the measurement of the photographic magnitudes of about 68,000 stars extending to an average limiting magnitude of about 18.5. It has required a study of methods for establishing a scale of magnitudes over a wide range of brightness; the determination of the brightness of the stars in the North Polar Sequence; measurements of standards of magnitude in each Area; derivation of corrections for distance from the center of the field; and standardization of the zero point of the magnitudes in each of the Areas by intercomparison photographs. The final magnitudes show a high degree of accordance with one another and with the scale of the North Polar Sequence, and, in addition to providing numerous standards well distributed over the sky, afford abundant material for the discussion of several of the problems of stellar distribution.

Stellar spectroscopic observations during the year have covered a wide field of activity. They have included the use of the 15-foot spectrograph for obtaining the spectra of bright stars on a very large scale, and of a new plane-grating spectrograph for the near infra-red region. Many spectrograms of faint stars of large proper motion, variable stars and faint components of visual binaries have been obtained with the low-dispersion spectrograph, and the standard Cassegrain instruments have been employed regularly.

Among the radial-velocity results of interest are the measurements of the relative velocities of the components of the Algol variables X Trianguli and RT Sculptoris by Joy; the determination of the velocity-curves of the Cepheid variables T Monocerotis, U Vulpeculæ and TU Cassiopeïæ by Sanford; and the derivation by Sanford of the orbits of two spectroscopic binaries, each of which is a component of a visual binary. Exceptionally large radial velocities of $+170$ km./sec. and -390 km./sec. have been found by Joy and Adams for the Cepheid variable AG Aurigæ and the short-period variable TU Persei, respectively. The velocity of TU Persei is one of the highest known for any star. Sanford's observations of the eclipsing binary RX Herculis have brought the mass of this star into agreement with Eddington's mass-luminosity relationship.

Strömberg has used the measurements of the radial velocities of giant stars of types K3 to K5 in a study of their motions in space. He finds that among the super-giant stars of these types the dispersion in velocity is small. The average peculiar radial velocity of the ordinary giants is 20 km./sec., and the solar motion derived from them is 25 km./sec. There is no trace of Kapteyn's two streams, but the asymmetry in velocity-distribution is very marked.

The spectra of numerous variable stars have been investigated by Joy, Merrill and Sanford. In the case of the Algol variable U Sagittæ, Joy has determined the velocity-curve and combined his results with the photometric elements to determine the absolute dimensions of the system. The larger star, which is also the fainter, gives out only 7 per cent of the total light; it is a typical giant of type G2, with a mass one-third that of the brighter star and a density one-eightieth that of the sun. Its diameter is 5.5 times that of the sun, while the brighter star of type B9 has a diameter

3.3 times that of the sun and a mass 5.8 times as great. Absolute dimensions have also been derived by Joy for the variable stars RT Lacertæ and RS Canum Venaticorum, both of which show spectra with double lines.

Merrill has studied the relative intensities of certain pairs of emission lines in the spectra of long-period variables, and finds a progressive change in the same direction during the whole time within which the lines are present. The behavior of the bright lines, therefore, evidently does not depend solely on the apparent brightness of the photosphere.

An interesting discovery by Merrill is his identification of many of the prominent emission lines in the spectra of η Carinæ and certain M-type variables, with forbidden lines in the ionized iron atom. These lines arise through transitions from metastable states at intermediate levels to the two lowest states, and have never been observed in the laboratory. An observation of the spectrum of the irregular variable RT Serpentis by Joy in June 1928 showed the presence of many of the forbidden lines and some remarkable changes in other spectral characteristics. The forbidden lines have also been observed in the spectra of several B-type stars with bright lines which have been under investigation by Merrill, Humason and Miss Burwell.

Further stellar spectroscopic investigations have included a detailed study of the spectrum of α Persei with high dispersion by Dr. Dunham, the classification of the spectra of the separate components of double stars by Dr. Leonard, and the continuation of observations of the spectra of faint stars in the Selected Areas by Humason. In the course of Dr. Dunham's investigation about 1,800 lines were measured, more than 90 per cent of which have been identified. The atomic energy levels from which the lines arise and their multiplet designations have been determined, and the measurement of their absolute intensities is in progress.

The absolute magnitudes of about 400 stars of types K3 to K8, including both giants and dwarfs, have been determined by Adams, Joy and Humason by the spectroscopic method. Strömberg has made an investigation of the values for the giants and a determination of their probable errors. Twenty-eight of the stars may be classed as super-giants with a mean absolute magnitude of -1.4 . The remaining giants have a magnitude of -0.1 and show a dispersion of 1.3 magnitudes.

In addition to the usual classification and derivation of absolute magnitude of all the stars observed, special investigations have been made of faint components of stars of large proper motion, and of the Cepheid variables. The results so far obtained for the Cepheids indicate that absolute magnitudes can be derived by an extension of the reduction system employed for ordinary giants of similar spectral type. A close correlation seems to exist between spectral type and absolute magnitude.

Russell and Adams have used the high-dispersion spectrograms of bright stars in an investigation of the amounts of metallic vapor present above stellar photospheres, and of the temperatures and other physical conditions in stellar atmospheres. On the assumption of thermodynamic equilibrium, an equation may be derived which connects the relative numbers of atoms producing the same line in different stars with the relative numbers of normal neutral atoms, the excitation potential, the state of ionization, and

the temperatures and electron pressures. The results indicate a serious departure from thermodynamic equilibrium in stellar atmospheres, which results in an excess of the relative number of atoms in excited states above that indicated by theory. After correction by an empirical method for the effects of this anomaly, temperatures are derived which are in excellent agreement with those found by other methods. The amounts of metallic vapor above equal areas of the photosphere of the cooler c-stars like α Orionis seem to be of the order of 100 times as great as in the case of the sun; and the strength of the enhanced lines in such stars suggests that they are produced largely in extensive chromospheres supported by radiation pressure.

The measures of stellar radiation accumulated by Pettit and Nicholson during recent years have been completely reduced and the results applied to the computation of the absolute bolometric magnitudes, temperatures and diameters of a considerable number of stars. Betelgeuse and Antares are found to have the brightest radiometric magnitudes, followed by Sirius, Canopus and γ Crucis. Stars of low temperature do not, in general, radiate like black bodies, the deviation in the case of long-period variables amounting to 2.5 mags. in heat-index, and 0.4 mag. in water-cell absorption. Several of these variables at maximum have computed diameters ranging from 0'.022 to 0'.047. The calculated diameter of Sirius is 0'.005; of Procyon, 0'.007; and of Capella A, 0'.011.

Measurements of the diameter of Betelgeuse by Pease with the 20-foot interferometer gave a value of 0'.037 for the epoch, February 1928. During most of the winter months observing conditions were unfavorable to the exacting requirements of this instrument.

In the Physical Laboratory, King has made extensive investigations of the spectra of several of the rare earths. This work has included the measurement of the wave-lengths of several thousand lines, mainly on spectrograms taken with the electric furnace; the separation of the lines of the neutral from those of the ionized element; their temperature classification; and a special study of many of the complex lines, especially of praseodymium, with high dispersion. The ultra-violet spark spectrum of the doubly-ionized atom of each of these elements has also been investigated. The separation of neutral from enhanced lines is difficult because of the low ionization potentials of the rare earths, and frequent use has been made of the method of suppressing the enhanced lines by introducing into the electric furnace an element like cesium of still lower ionization potential. These investigations have been of great assistance in the identification of rare earths in the solar spectrum.

An analysis of his measurements of the displacements of iron lines under pressure has enabled Babcock, by means of two empirical equations, to define, for spectral terms of different multiplicity, the change of level produced by a difference of one atmosphere in the pressure at the source of light. The Mount Wilson classification of spectral lines has thus been given a numerical basis which should add to its value. It appears that a difference of one temperature class in the furnace classification of King corre-

sponds to a change of about 0.7 volt in the excitation potential, except in the case of calcium, where it is 0.35 volt.

Anderson has been particularly interested in the strong continuous spectrum shown by vacuum tubes through which a heavily condensed discharge is passed. Using tubes of various sizes charged from the two-microfarad condenser to voltages of 3,000 to 35,000 volts, he finds, at a current density of about 20,000 amperes per square centimeter, a sort of "saturation" value beyond which the increase in intensity of the continuous spectrum with current is slight. At current densities less than 10,000 amperes per square centimeter, the continuous spectrum is practically absent. These results are for an initial gas pressure of 0.5 mm. of mercury in a tube 10 cm. long viewed end-on. For shorter tubes, or for a tube 1 cm. in diameter viewed side-on, a saturation value of somewhat above 30,000 amperes per square centimeter is indicated. From these results it follows that a layer of gas in a 10-cm. tube 1 cm. in thickness is sensibly opaque to incident radiation. A promising method is thus afforded for determining the absorption coefficient of gases at high temperatures, a quantity of increasing importance in astrophysical problems.

An attempt has been made by Smith to produce in the laboratory the forbidden lines of ionized oxygen and nitrogen found in the spectra of gaseous nebulae. Vacuum tubes of various forms excited in many different ways were tried but, although a spectrum rich in lines of $O II$ and $O III$ was obtained, the forbidden lines did not appear. A 4-meter wave vacuum-tube oscillator was constructed for this investigation, which has been used in the study of the spectra of several gases. An increase in the intensities of the higher members of the various series of lines is the most characteristic feature of these spectra.

Pettit has carried out a variety of laboratory investigations, including the measurement of the radiation of arc lamps in the ultra-violet region λ 0.29 μ to λ 0.31 μ , the optical properties of fused and crystalline quartz, and the photochemical changes in glass. In the mercury arc he finds that only about 25 per cent of the total radiation emitted is given by the individual lines, the hot mercury vapor contributing much infra-red radiation. The fraction of the total radiation given in the region λ 0.29 μ to λ 0.31 μ varies from 0.007 for a power consumption of 100 watts, to 0.051 for 400 watts.

The study of fused quartz lenses shows that in all the cases examined a reticulated structure is present, due probably to the fusion surface of the crystals used in their manufacture. In some cases, as in that of a 6-inch lens used for ultra-violet photography of the sun and moon, the chief effect is scattered light in the image, but in others, where striæ are seen, multiple images are produced. The importance of the selection for its optical properties of the crystalline quartz intended for the manufacture of optical fused quartz is emphasized by these results.

A type of optical oscillograph possessing a number of advantages over any now in use for recording variations of current during an extremely short interval, such as a wire-explosion, has been designed and constructed by Smith. The current to be studied passes through a solenoid surround-

ing a cell containing carbon bisulphide. Variations in the current affect the plane of polarization of a beam of light which passes first through a nicol prism and quartz plate, and then through the cell and a second nicol prism. The emergent light, as seen through a spectroscope, consists of a series of dark and bright bands, and can be photographed with a rotating-mirror spectrograph.

Additional laboratory investigations have included King's work on ultra-violet arc and spark spectra of several elements, the principal neutral and enhanced lines of erbium, and the line and band spectra of boron; Babcock's revision and compilation of standards of wave-length; Smith's successful development of a long-period vertical seismometer; and several studies by Pettit of photochemical changes in the ultra-violet transmission of glass, and the transmission of organic liquids and filters in the ultra-violet or infra-red. Dr. Russell in collaboration with Dr. Meggers of the Bureau of Standards has completed an analysis of the arc and spark spectra of yttrium, which is now ready for publication.

Strömberg and Pease have repeated the experiment of Esclangon, made in 1927, which appeared to indicate the existence of an ether-drift or of a non-isotropic character of space. Their apparatus was mounted on a turn-table floating in mercury and was rotated slowly in one direction and then the other. The displacements of the fringes were found to be extremely small, seldom exceeding 0.02 , and did not seem to be in any way systematic. Esclangon's values showed an amplitude of 0.05 and varied with the sidereal time.

Attempts to use the 82-mile base-line between Mount Wilson and Mount San Jacinto for measurements of the velocity of light were interfered with so seriously by smoke and haze that Dr. Michelson decided in June to move the distant station to Santiago Peak, about 50 miles from Mount Wilson. Conditions thus far have been unfavorable for observations, but further trials will be made. In the meantime, Dr. Michelson has devised a method for carrying on the measurements in a pipe line exhausted of air, about half a mile in length. Such a plan would have many important advantages over the usual method, and will probably be adopted if atmospheric conditions prevent the use of the Mount Wilson-Santiago Peak base-line.

Observations have been continued by Dr. Michelson, Pearson and Pease on the ether-drift experiment, and the apparatus has been used in a variety of forms. Several hundred measures made with the 11-foot rotating steel and invar interferometer showed no displacement of the kind observed by Professor Miller, which varied with sidereal time, but residual disturbances amounting to several hundredths of a fringe were found which were ascribed to a combination of temperature effects and strains in the interferometer frame. The interferometer was then set up on a 100-inch cast-iron plate floating in an annular tank filled with mercury. The apparatus was enclosed in a double room and observations were made from without. The measurements of Pearson and Pease give a negative result even more decisively than before, and show that the disturbing factors have been almost completely eliminated.

OBSERVING CONDITIONS

The number of clear nights during the year ending June 30, 1928, was considerably above the average for the past 16 years. The 60-inch telescope was in use 2,417 hours as compared with an average of 2,236 hours per year. In only one year, 1917-18, has this number been exceeded. The telescope has been in actual use 62 per cent of the night hours since 1912.

As seems to be characteristic, however, of years of deficient rain-fall and of prevailing northerly winds during the winter, conditions of seeing have been below the average. The precipitation for the year was only 20.56 inches as compared with a 24-year average of 33.10 inches. The total snowfall amounted to 36 inches. The highest temperature recorded was 97° on July 18, and the lowest was 18° on January 16. Meteorological records for the use of the Government Air-mail Service have been continued regularly, and have included special observations of wind-velocity and direction, humidity, fog-elevation and transparency. The following table compiled from the records kept for the 60-inch telescope summarizes the night observations with this instrument.

Month	Hours of darkness	Hours of observation	No. observations	Observations		
				All night	Part night	None
1927						
July.....	255	245	10	27	4	0
August...	269	265	4	27	4	0
September	295	246	49	25	3	2
October...	336	234	102	23	2	6
November.	330	173	157	13	9	8
December.	346	127	219	14	2	15
1928						
January..	346	220	126	17	9	5
February.	317	179	138	17	5	7
March....	324	140	184	12	6	13
April.....	286	191	96	14	13	3
May.....	266	186	80	20	7	4
June.....	230	211	19	25	5	0
Totals..	3,600	2,417	1,184	234	69	63
Mean 16 years.....		2,236	1,360	192	93	80

Interest on the part of the public in the visual observations on Friday evenings has continued to increase, and 5,005 persons have used the 60-inch telescope on these occasions. As in other years an illustrated lecture has been given each week, immediately before the public observations. Approximately 12,000 persons have visited the astronomical exhibit and inspected the 100-inch telescope during the daily afternoon periods when these are opened to the public.

SOLAR RESEARCH

Solar activity was considerably greater during the first half of 1927 than during the last, although sun-spots, prominences and eruptive phenomena

have been numerous throughout the entire year. Measurements of the numbers, intensities of magnetic field and polarities of sun-spots have been made regularly, as in previous years. Special studies of important prominences, of the spectra of sun-spots and of the disc in the extreme red, and of the unusual behavior of the spectral lines of complex sun-spot groups have formed an increasingly large portion of the program of solar research. Rotation plates of the solar spectrum taken at the center and at the limb of the sun have greatly facilitated the differentiation of solar and atmospheric lines. Considerable work has also been done on the identification of additional elements in the sun.

SOLAR PHOTOGRAPHY

Direct photographs of the sun have been made with the 60-foot tower telescope on 299 days. During 15 days in the latter part of May and early in June the telescope was not in use, and no photographs were obtained, owing to alterations which were being made in the cœlostæt mounting and driving clock. The following spectroheliograms have been obtained by the solar observers, Ellerman, L. H. Humason, Nicholson, Perrakis, Pettit and Richardson:

With the 5-foot spectroheliograph on the 6.5-inch image, 156.

With the 13-foot spectroheliograph on the 2-inch image, 444 plates in $H\alpha$, 301 in K_2 , and 289 prominence plates in K .

As in other years, a special series of negatives and data regarding the observations have been sent regularly to the Kodaikanal Observatory in accordance with the plan of cooperative investigation of solar activity.

Several photographs of the sun in ultra-violet light of wave-length 0.32μ have been made by Pettit, using a silvered 6-inch fused quartz lens mounted equatorially. These are compared with photographs taken through a glass lens and a solarized green celluloid filter in light of wave-length greater than 0.7μ . The ultra-violet negatives show areas of faculæ about sun-spot groups similar in some cases to those shown on calcium spectroheliograms.

SUN-SPOT ACTIVITY

The number of groups observed daily during 1926 remained about constant until near the end of the year, then increased to a maximum occurring in March 1927. The marked decrease in spot activity which followed in June was characteristic of the remainder of 1927. Another period of increased activity occurred during the first part of 1928, although the high level of March 1927 has not, as yet, been reached.

Solar observations were made on 312 days in 1927, and on all of these days spots were present. August 9, 11 and 12 were the only days when less than two groups were visible. A total of 424 groups was observed, 51 more than last year. This increase was almost all in the southern hemisphere, where the number of groups was 237 in 1927, 188 in 1926 and 116 in 1925, while in the northern hemisphere the numbers for these years were 187, 185 and 183, respectively. The average number of groups observed daily during each month was as follows.

Month	Daily Number			Month	Daily Number	
	1926	1927	1928		1926	1927
January...	7.0	6.5	6.8	August....	5.2	3.9
February..	5.1	8.6	6.3	September.	5.6	6.3
March.....	6.0	7.4	6.9	October....	5.6	6.0
April.....	4.8	8.3	6.9	November..	6.1	5.6
May.....	5.6	8.1	5.4	December..	6.8	3.9
June.....	6.8	6.1	7.1	Yearly Average.	5.9	6.3
July.....	5.7	5.0				

During 1927 the mean distance of spots from the solar equator was $15^{\circ}5$. The spot zone approached the equator somewhat faster than during the corresponding phase in the last cycle. In November and December 1927, the mean latitude was $12^{\circ}3$ in the northern and $12^{\circ}2$ in the southern hemisphere. These values are well below the average for the last few cycles, and offer further evidence that the maximum is probably now past.

In cooperation with the Harvard and Yerkes Observatories, the work begun in January 1927, of supplementing the Naval Observatory record of areas and positions of sun-spots, published regularly in the Monthly Weather Review, has been continued.

SUN-SPOT POLARITIES

Records of the polarity and intensity of the magnetic field in sun-spot groups were made on 295 days in 1927. The table shows the results of the observations. Groups listed as regular in the northern hemisphere show S (south-seeking), or negative, polarity for the preceding spot, and N polarity for the following spot, while in the southern hemisphere the opposite is the case. Spot groups having reversed polarities are listed as irregular; but complex spot groups, even though they sometimes have partially reversed polarities, are listed as regular. If the polarity and intensity of a sun-spot could not be observed on at least one day, the spot was omitted from the table.

Hemisphere	Polarity	
	Regular	Irregular
North.....	174	3
South.....	220	8
Whole Sun.....	394	11
Total.....		405

TERRESTRIAL MAGNETISM AND SOLAR ACTIVITY

In cooperation with the Department of Terrestrial Magnetism, a magnetograph was installed on Mount Wilson in August 1926. Previous to April 18, 1928, the intensity of the horizontal component alone was recorded. Another magnetograph was then installed to record the variation in the magnetic declination. Both instruments record simultaneously on the same sheet of paper. Since the horizontal component shows more individual variations than the declination, it has been used for comparison with the daily solar observations in an attempt to discover the type of solar activity responsible for particular magnetic disturbances.

Magnetic disturbances were more numerous and more intense during May and June 1928 than at any other time this year. In general, they accompanied large, active and complex spot-groups. The hydrogen spectrohelioscopes always showed intense activity near any spot group which seemed to be directly responsible for a magnetic storm, and in some cases certain lines of the spot spectrum showed very unusual behavior.

THE SPECTROHELIOSCOPE

Mr. Hale's work with the spectrohelioscope during the past year has included a further study of the fields of force in the solar atmosphere, the improvement of the large vertical spectrohelioscope of the Solar Laboratory in Pasadena, and the development of a smaller horizontal solar telescope and spectrohelioscope for use by amateur and professional astronomers. (See *An Inexpensive Solar Telescope and Spectrohelioscope*, *Nature*, April 28, 1928.)

As in the case of the spectroheliograph, a monochromatic image of the sun can be produced either by motion of narrow slits with respect to the solar image, or by motion of the solar image with respect to fixed slits. The chief difference between the two instruments lies in the fact that the spectroheliograph builds up its image gradually, slit-width by slit-width, by a slow motion of the slits, or of the solar image with respect to the photographic plate, while the spectrohelioscope reveals a considerable area of the image at once to the eye, which obviously could not see the forms of the flocculi through the slowly moving slits a few thousandths of an inch wide. Hence, the rapid motion of the slits or of the solar image required for the spectrohelioscope.

Three systems of moving slits have been successfully tried:

(1) An oscillating bar carrying single slits at each end.

(2) An oscillating bar carrying three or more slits at each end. By increasing the number of slits the rate of oscillation necessary to avoid flicker may be reduced, with corresponding reduction in any effects of vibration.

(3) A rotating disc carrying fifty radial slits.

Three means of producing rapid motion of the solar image with respect to fixed slits have also been devised:

(1) An oscillating plane mirror, so mounted in conjunction with a second plane mirror that the second slit can be viewed in another part of the same mirror system. This was suggested by Sinclair Smith.

(2) A square prism of glass, mounted before each of the slits, rotating uniformly about an axis parallel to them. The portion of the solar image under observation reaches the first slit through one prism, while the resulting fixed monochromatic image is seen in an eye-piece focused through the other prism on the second slit. This device is due to Anderson.

(3) An oscillating right-angle prism, mounted with its edge parallel to the slits and its hypotenuse surface normal to their plane. In this arrangement, previously used in a somewhat different form on the spectrohelio-graphs of our 60-foot and 150-foot tower telescopes, the solar image moves at twice the speed of the prism.

All three of these devices are here supposed to be used with a spectro-scope in which the apparent motion of the solar image, as observed through the second slit, is opposite in direction to the actual motion of the solar image across the first slit. In this case, when looking at the second slit through an extension of the oscillating or rotating optical system which causes the motion of the solar image, the effect of this motion is exactly compensated and the monochromatic image appears at rest. The same devices can be adapted for use with spectroscopes of other types.

Seven complete solar outfits, each including a cœlostat telescope of 4-inches aperture and 18-foot focal length, and a spectrohelioscope of 13-foot focal length equipped with rotating prisms before fixed slits, are being built in our instrument shop. Anderson's ingenious method of rotating prisms, affording complete freedom from vibration and flicker, was chosen by Hale for these outfits in preference to oscillating slits. The instruments will be used at a number of solar observatories distributed around the world for a study of the relationship between solar eruptions and such terrestrial phenomena as auroras, magnetic storms and variations in radio transmission.

The spectrohelioscope not only renders visible bright and dark hydrogen flocculi and prominences on the sun's disc and at the limb, but is also especially adapted to the measurement of their velocities in the line of sight and the study of the resulting complex-line distortions. These distortions have been known since the earliest days of solar spectroscopy, and the radial velocities at any series of points can be measured directly at the spectro-scope, or on photographs of successive sections made with the velocity-spectrograph of Deslandres. The advantages of the spectrohelioscope in quickly interpreting them must be seen to be appreciated. The "line-shifter" serves in somewhat the same way as the "blink" device of a Zeiss stereocomparator, but instead of merely indicating, in a very striking way, any differences between two photographs, it shows at a glance the connection of a series of related phenomena by linking them into a sequence. This is what is referred to in one of Hale's papers as "a new effect of inflow," by which is meant the motion of the maximum of intensity along a flocculus due to progressive differences in radial velocity, at once interpreted by the line-shifter.

Similar solar telescopes and spectrohelioscopes are also under construction by several amateur astronomers, and have been ordered by a number of observatories and physical laboratories. This should result in a useful development of solar research.

GENERAL MAGNETIC FIELD OF THE SUN

The attempt to measure with the registering microphotometer the very small displacements of lines due to the general magnetic field of the sun has led to a general study by Pettit and Miss Ware of the mechanical action of this instrument. Several improvements, which include the use of a lighter microscope stage and a driving motor operated by a storage battery, have increased its accuracy of performance. The optical system has also been greatly improved, and the microscope has been so arranged that the progress of the registration can be followed visually.

A preliminary determination of the displacement made from a photograph taken at solar latitude 60° N gave a value of $+0.011$ mm. The displacement as measured previously by van Maanen was $+0.010$ mm.

SUN-SPOT SPECTRA

During the year 36 photographs of sun-spot spectra were obtained with the 150-foot tower telescope by Ellerman, L. H. Humason and Richardson. Of these, 26 were in the near infra-red. Satisfactory determinations of the intensities of sun-spot lines have now been made as far as λ 8500.

THE INFRA-RED SOLAR SPECTRUM

Recent improvements in the sensitiveness of photographic emulsions to infra-red light, and marked efficiency in the apparatus used, have made it possible for Babcock to bring an extensive new region of the solar spectrum under detailed photographic examination. The previous limit in this region was λ 9867, reached by Captain Abney nearly 50 years ago. Babcock has succeeded in photographing lines as far as λ 10900 with a concave-grating spectrograph, and, with lower dispersion and a prismatic spectrograph, has obtained negatives showing the principal lines as far as λ 11900. About 600 new lines have been measured, none of which had been photographed previously. Among these is the strong line of hydrogen at λ 10049.4, which forms the fourth member of the Ritz-Paschen series. This line is about as wide as $H\alpha$, but probably less black. The standards of wave-length between λ 6900 and λ 8980, previously determined by Babcock with the interferometer, have formed the basis for the new observations.

A great absorption band due to terrestrial water-vapor obscures much of the solar spectrum between λ 9000 and λ 10000. Beyond λ 10000, however, the extensive map of the solar spectrum obtained with the aid of the bolometer by the observers of the Smithsonian Institution shows hundreds of lines, many of which are undoubtedly of solar origin. Babcock has undertaken the identification of these lines, and has already been able to assign about 40 solar lines between λ 8500 and λ 17550 to the spectra of the lighter alkalis and alkaline earths. These preliminary identifications are among those obviously to be expected from the series relations involved. The apparent absence from the solar spectrum of a few similar lines may be ascribed either to the low resolving power of the bolometric apparatus, or to the masking effect of telluric bands.

CALIBRATION OF ROWLAND'S SCALE OF INTENSITIES FOR SOLAR LINES

The relative intensities of the lines in multiplets can be expressed by formulæ, based on the correspondence principle, which involve only the quantum numbers of the lines; although approximate, these formulæ can probably be depended upon to give correct average results. Since these theoretical intensities may be assumed to be proportional to the numbers of atoms active in producing the lines, the way is open to a calibration of Rowland's scale in terms of the number of active atoms N .

Such an investigation has been made by Dr. Russell, Adams, and Miss Moore. Data for 228 multiplets give a provisional relation between $\log N$ and Rowland's intensity R , which is found to depend on wave-length. Correction by successive approximations gives finally $\log N = B \log A$, where A is a function of R , and B is a function of the wave-length. Tables of $\log A$ have been derived for values of R ranging from 0000 to 40. This formula is generally applicable to all the elements studied, but uncertainty in the zero point restricts its use to neighboring lines. Even for such lines it gives only relative values of N .

REVISION OF ROWLAND'S TABLE OF SOLAR SPECTRUM WAVE-LENGTHS

The manuscript of this extensive catalogue is now (June 30) in the hands of the printer, and since the tables are to be reproduced by a photographic process the publication may be expected within a few weeks. The preparation of the material has been the work of St. John, assisted by Miss Moore, E. F. Adams and Miss Ware. The extension of the table toward the infra-red, from λ 7333 to λ 10218, is due mainly to the measurements of Babcock.

The total number of lines between λ 2975 and λ 10218 listed in the table is 21,835, of which 11,377 have been identified. Fifty-seven of the 92 chemical elements have been recognized by their lines in the sun. Three of these, iridium, lithium and rubidium, all of low ionization potential, have been identified only in sun-spot spectra. Boron occurs in spots as boron oxide, while sulphur is identified somewhat doubtfully by one or two lines in the infra-red. The line of ionized helium at λ 4685.808 appears in the flash spectrum, and the energy of 72.57 volts required for its production is the highest observed for any element in the sun. The only case of possible second-stage ionization is that of λ 3055.592 which may perhaps be due to Ce III.

Nitrogen is found to occur in the atomic state as well as in the diatomic molecules CN and NH . Carbon also appears in the atomic state, and in the molecular forms CN , $C-$, and CH , which are the sources of the cyanogen, Swan, and hydrocarbon bands, respectively. Oxygen shows, in the free state, five lines in the infra-red, and forms with hydrogen the diatomic molecule OH , which gives rise to the so-called water-vapor bands in the ultra-violet. Oxygen also combines with titanium to produce the well-known bands in spots.

Twenty-five elements are represented by neutral atoms alone, 19 by both neutral and ionized atoms, and 13 by ionized atoms only. For a given element the percentage of ionized lines is related closely to its position in

the periodic table; and for different elements the percentage of ionized lines increases with decrease of the energy required for their production. This is illustrated in the following table:

Quantum orbit	Elements	Mean energy-level	Mean percentage of ionized lines
3	<i>Mg, Al, Si</i>	15.10 volts	12.3
4	<i>Ca, Sc, Ti, V, Cr</i>	8.59	24.6
5	<i>Sr, Y, Zr</i>	7.09	47.6
6	<i>Ba, La</i>	6.43	100.0

Mn, Fe, Co and *Ni* in the 4-quantum orbit form a close group with a mean energy-level of 10.08 volts, and only 3 per cent of their lines ionized.

GRAVITATIONAL DISPLACEMENT OF SOLAR LINES

From a discussion of the measures of 1,537 lines at the center of the sun and 133 at the edge, St. John finds the following results. The mean displacement at the center of the sun of lines of medium level (520 km.) in the solar atmosphere is $+0.009$ A, as compared with Einstein's predicted displacement of $+0.0091$ A. For lines of higher level (840 km.) it is 0.0027 A greater, and for lines of low level (350 km.) 0.0026 A less, than the calculated value.

At the edge of the sun, however, the lines of very low level, which, at the center show less than the predicted displacement, give the calculated value, the effect of any upward currents near the photosphere having vanished at the sun's edge. The conclusion is that the differences between solar and terrestrial wave-lengths are due to gravitational displacements, modified, in the case of low-level and high-level lines, by conditions equivalent to radial velocities whose effects vanish at the edge of the sun. A mean displacement derived from 133 lines of iron at the limb, which is 0.0015 ± 0.0004 A greater than that calculated from the theory of generalized relativity, must, if real, represent the actual "limb" effect.

ROTATION OF THE SUN

The results obtained by St. John for the linear equatorial velocity of the sun during successive years are as follows:

1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1928
1.92	1.96	1.91	1.94	1.95	1.90	1.90	1.91	1.91	1.89	1.91	1.89 km./sec.

All of these values have been obtained with the same instrumental equipment and by the same observers. They show a large deviation from the value 2.06 km./sec. found by Adams and Miss Lasby in 1908.

ABSOLUTE INTENSITIES OF SOLAR LINES

Investigations are now in progress by St. John to determine the total absorption of a considerable number of selected lines, and the changes in their absorption and contours as between the center and edge of the sun. A number of multiplets has been selected for the purpose so that the theoretical intensities of the individual lines may be compared with the observed values. Multiplets belonging to both the neutral and the ionized atom of several elements are included. A portion of the preliminary work in this investigation has been completed.

ULTRA-VIOLET SOLAR RADIATION

Measurements of the solar radiation at $\lambda 0.32\mu$ transmitted by a silver film have been continued by Pettit on every clear day throughout the year with the use of the ultra-violet solar radiometer. Nearly 1,000 plates, most of which cover a day's run with the instrument, have been taken since 1924. The smoothed curve of monthly averages, made by taking means for every three months of the ratios of ultra-violet (0.32μ) radiation to green (0.50μ), shows marked parallelism to the curve of sun-spot group numbers formed in similar fashion. The halt in the summer of 1925, the maxima in the autumn and winter of 1925 and 1926, the minima of the summers of 1926 and 1927, and the present rise in the summer of 1928 show alike in both curves. The increase in the amount of ultra-violet light amounted to 50 per cent at the two maxima, and the decrease to 30 and 20 per cent, respectively, at the two principal minima. These observations show the sun to be a variable star with most of the variation in ultra-violet light.

The measurement of the ultra-violet radiation from the sky has been undertaken with a silvered photoelectric cell. This is attached to a recording device which automatically registers a zero mark with a piece of glass at intervals of a few minutes. A study of the records of the radiation from the sun *plus* sky in Pasadena shows the following results:

(1) On a typically clear day the whiteness of the sky, which increases considerably about 11 A.M., cuts down the radiation at $\lambda 0.32\mu$ about 5 to 10 per cent.

(2) From 10 to 25 per cent as much radiation at $\lambda 0.32\mu$ is received on a completely cloudy day as on a perfectly clear day.

(3) On clear days as much radiation is received from the sky as from the sun.

(4) In certain kinds of hazy weather as much radiation is received from the sky as on clear days is received from the sun *plus* sky.

(5) The amount of sky radiation on a clear day is proportional to the altitude of the sun.

The distribution over the sky of the radiation at $\lambda 0.32\mu$ has also been measured, and its variability with different conditions of sky has been studied. Increased haze increases the radiation in all parts of the sky, but the area within 20° of the sun is affected most. Measurements of sun *plus* sky radiation for $\lambda 0.32\mu$ at Pasadena, Mount Wilson, and a point about two-thirds the distance up the mountain, show an increase of only

about 6 per cent on Mount Wilson, although the sky in Pasadena radiates twice as much as that on the mountain.

Spectrograms of the radiation from the sky taken with the 1-meter concave grating spectrograph and a quartz monochromator show radiation down to $\lambda 0.293\mu$. From the exposure times of these photographs, as compared with similar ones on the sun, it appears that the radiation from the sky at $\lambda 0.30\mu$ is about equal to that of direct sunlight. A more exact determination of this ratio is in progress.

PLANETARY AND LUNAR OBSERVATIONS

DIRECT PHOTOGRAPHY OF THE MOON

Pettit has used the equatorial mounting designed for recording drift-curves to secure photographs of the moon in ultra-violet and near infra-red light. The instrument is provided with two 6-inch lenses, one of glass and the other of fused quartz. A silver film on the quartz lens transmits wave-lengths near 0.32μ , and a solarized green celluloid filter used with the glass lens transmits light of wave-length greater than 0.7μ . Several areas on the moon, particularly on the east limb after the last quarter, show much greater relative intensity on photographs in ultra-violet than in infra-red light. For many of the exposures a quartz enlarging camera was used.

PHOTOGRAPHS OF VENUS

Dr. Frank E. Ross, of the Yerkes Observatory, continued throughout June and a part of July 1927 his photographs of the planet Venus, with results of great interest. A series extending over 25 nights, as nearly consecutive as possible, was obtained during this exceptionally favorable eastern elongation of the planet.

Details over the disk which are interpreted as cloud formations appear on all the photographs taken in ultra-violet light. These are very weak in blue-violet or blue light, and red and infra-red exposures show no details. Dr. Ross concludes that the outer atmospheric layer of Venus is composed of a thin stratum of cirrus clouds, while the inner atmosphere is exceedingly dense and yellowish in color. The details shown are atmospheric disturbances, visible either as dark areas or as regions of enhanced brightness, according to the character of the disturbance.

The bright areas generally appear near the cusps, which are presumed to be near the poles, while the dark areas are usually in the form of bands parallel to the equator. The banded appearance and the rapid changes of these areas make it probable that the period of rotation of the planet can not be nearly so long as the orbital period. Spectrographic observations, on the other hand, show that the rotation period can not be short. A value of about 30 days is suggested as a compromise between these conflicting indications.

Measurements of the diameter of Venus in ultra-violet light give values about 2 per cent greater than those in red light, although such photographic determinations are subject to large systematic errors. The adopted value of the diameter is $17''00$, corresponding to a linear diameter of 7,651 miles,

or 12,313 km. The mean density is 0.919 that of the earth, a value higher than that found in previous determinations.

Intensity curves derived from density curves made with the registering microphotometer show the distribution of light over the disk for various colors. The variation is such that it seems probable that the upper surface of the cloud layer is uniformly billowy in character. Measurements of the relative amounts of light from the dark and adjoining bright areas show a maximum difference of 24 per cent on the ultra-violet photographs, and only 4 per cent on those made in blue light.

RESEARCHES ON NEBULÆ

DISTRIBUTION OF FAINT NEBULÆ

In continuation of his general survey with the large reflectors, Hubble has secured about 150 photographs, mainly in low galactic latitudes. The program as planned involves the accumulation of about 450 photographs distributed uniformly over the portion of the sky within reach.

THE ANDROMEDA NEBULA

The preliminary investigation of stars in the great spiral nebula of Andromeda, M 31, has been completed by Hubble, and the results have been prepared for publication. Of the 50 known variable stars, 38 have been identified as Cepheids. These show a conspicuous period-luminosity relationship, with reference point displaced about 0.1 mag. beyond those for M 33. The distance of M 31 is, therefore, about 5 per cent greater than that of M 33. As in the case of M 33, the brightest variables are irregular in light and probably analogous to those found in M 81, M 101 and N.G.C. 2403.

Statistical studies of the 86 novæ observed in M 31 indicate a frequency of between 25 and 30 a year. A mean light-curve has been derived, similar to that for galactic novæ. The magnitudes at maximum fall within a restricted range of 3 or 4 magnitudes, and the distribution can be represented by an error curve in which the probable error for a single maximum is of the order of 0.5 mag. The maximum frequency is at apparent photographic magnitude 16.5, or absolute magnitude -5.7 , at the distance indicated by the Cepheids. The restricted range is well established, since the observations of variables go well beyond the faintest of the novæ, and should have considerable significance in connection with the study of galactic novæ.

The distribution of the novæ in M 31 follows the distribution of the luminosity in the nebulous material, while that of the Cepheids follows the distribution of the very bright giants into which the outer portion of the nebula is resolved.

DENSITY FUNCTION OF EXTRA-GALACTIC NEBULÆ

Counts of nebulæ have been made by Hubble on some 250 long-exposure photographs taken with the large reflectors in regions of high galactic latitude. The results, when reduced to a homogeneous scale, indicate a marked correlation between exposure times and numbers of nebulæ, the numbers increasing at approximately the theoretical rate for uniform distribu-

tion in depth. The only important assumption involved is that the distribution over the sky in high galactic latitudes is approximately uniform. For the small nebulae this is supported by the evidence available at present, but, in view of the importance of the question, a new investigation has been commenced, based upon a more systematic survey.

The correlation diagram has been calibrated by means of long-exposure extra-focal photographs of stars in the Selected Areas. The results indicate that the 170 nebulae per square degree, which are shown on negatives taken with an exposure of 2 hours on Eastman 40 plates with the 100-inch reflector, include nebulae to a total photographic magnitude of 19.5 or 19.6. On the assumption of a color-index of one magnitude, and with reasonable allowance for obscuration in low galactic latitudes, these data are consistent with the results previously derived for the brighter nebulae, and indicate that the density-function of extra-galactic nebulae is sensibly uniform up to the efficient limits of the 100-inch reflector.

NEBULAR SPECTROSCOPY

The irregular non-galactic nebula N.G.C. 6822 has been shown by Hubble to resemble the Magellanic Clouds. At its northern edge is a comet-shaped patch of emission nebulosity with several stars involved. Humason has obtained four spectrograms of this object with a low-dispersion spectrograph, and from measures of the emission lines $H\gamma$, $H\beta$, N_1 and N_2 , finds a radial velocity of -130 km./sec. This value probably represents the order of the velocity of N.G.C. 6822 as a whole.

A spectrogram of N.G.C. 205, the fainter and more distant companion of the Andromeda nebula, has been obtained by Adams, Humason, Joy and Sanford with an exposure of 45 hours. The radial velocity is found to be approximately the same as that of the Andromeda nebula itself and of its brighter companion, N.G.C. 221, or about -300 km./sec. The spectrum is of earlier type than that of the large nebula and has been classified as F5n.

Novae which have been observed spectroscopically during the year, chiefly by Humason, include Nova Aquilae 1927, magnitude, approximately 10.0; Nova Aquilae 1918, 10.5; and Nova Wolf 1927, 9.5.

Merrill has obtained with the plane-grating spectrograph measurable images of the lines $\lambda\lambda$ 7135.6, 7319.9, and 7330.4 in the spectra of the planetary nebulae N.G.C. 6572 and 7027. The detection of duplicity in the line near λ 7325 adds confirmation to Bowen's identification of it as a forbidden line of ionized oxygen.

RESEARCHES ON STARS

TRIGONOMETRIC PARALLAXES

The measurement of trigonometric parallaxes has been continued throughout the year by van Maanen. During this period he has obtained 135 photographs with 245 exposures at the primary focus of the 100-inch reflector, and 131 photographs with 248 exposures at the Cassegrain focus of the 60-inch reflector. Parallaxes have been derived from 17 fields, bringing the total number of completed fields to 256.

A discussion of the first 250 measured fields is given in Mount Wilson Contribution No. 356. It is found that the mean probable error of a parallax as derived from the photographs with the 60-inch telescope (80-foot focus) is less than $0''.006$, and that from photographs with the 100-inch telescope (42-foot focus) a little more than $0''.010$. A list of stars consisting of seven stars of type O, two of type N, five eclipsing variables, 12 Cepheids and 11 long-period variables, for which theoretical values of the parallax can be derived with considerable accuracy, has been used to determine the external probable error of van Maanen's values. This is found to be $0''.008$ on the assumption that the theoretical values are subject to no error. If we suppose that the theoretical values are in error by an amount which would correspond to one unit in absolute magnitude, the probable error would become $0''.007$. These values are in good agreement with the internal probable errors already given.

An extensive investigation has been made by van Maanen of systematic errors in the trigonometric parallaxes as determined at Mount Wilson and at the Allegheny, McCormick, Yerkes, Sproul, Greenwich and Dearborn Observatories. From a comparison of these series with one another and with the Mount Wilson spectroscopic parallaxes, van Maanen concludes that all of these parallaxes are affected by systematic errors which are a function of right ascension. The range in the corrections amounts to $0''.0096$ for Mount Wilson, $0''.0109$ for Allegheny, $0''.0096$ for McCormick, $0''.0188$ for Yerkes, $0''.0198$ for Sproul, $0''.0210$ for Greenwich, and $0''.0514$ for Dearborn. The discussion of this material and a table of the necessary corrections will appear in Mount Wilson Contribution No. 357. A new card catalogue of all published trigonometric parallaxes with these corrections applied has been completed.

PROPER MOTIONS

Thirty photographs with 31 exposures with the 100-inch reflector and 75 photographs with 139 exposures with the 60-inch reflector have been obtained by van Maanen for the measurement of proper motions. Most of these are first-epoch plates for the study of spiral nebulae and Cepheid variables.

At the request of Dr. Schilt, 18 photographs of the Orion nebula have been made for the purpose of studying the light-curves of the variable stars in this region.

STELLAR PHOTOMETRY

CATALOGUE OF SELECTED AREAS

The Mount Wilson Catalogue of Photographic Magnitudes had its origin in a request by Professor Kapteyn in 1909 for assistance in determining the brightness of stars in the Selected Areas. This request led to a series of related investigations which, with the completion of the manuscript for the catalogue itself, have now been brought to a close.

The results obtained at various stages of the undertaking have been described from time to time in previous reports and need only be summarized here. The original plan provided for an hour's exposure with the 60-inch reflector, supplemented by a 3-minute exposure on the same plate, to each

of the 139 Areas between the North Pole and declination -15° . These photographs were to be measured and reduced at the Astronomical Laboratory at Groningen with the aid of standard magnitudes derived at Mount Wilson.

The derivation of the standards required, first, an extended investigation of methods that might be used to establish a scale of magnitudes over a wide interval of brightness, and, second, the determination of the brightness of the stars of the North Polar Sequence, which have played an important part in the reduction of the measures for the Catalogue.

In the meantime, observations for the determination of the standards in each Area were under way. These were based on four plates of multiple exposure (two plates with 2-minute, and two with 15-minute exposures), made with full aperture, with diaphragms of various sizes, and with a wire gauze screen. Difficulties with the distance correction, which in itself necessitated a troublesome investigation, led to the conclusion that the results of the whole undertaking could be much strengthened by determining the magnitudes of all the stars visible on these plates, instead of only those for a limited number to be used as standards.

The adoption of this enlarged program has increased very considerably the reliability of the scale of the catalogue and the precision of the individual magnitudes. Further, since the fields measured at Groningen and at Mount Wilson are not wholly coincident, it has also increased the number of stars available for statistical investigations.

A very important item in the preparation of the Catalogue was the standardization of the zero point of the magnitudes in each of the Areas, which was accomplished by means of intercomparison photographs. The stars in each Area were connected with those of the adjacent Areas in the same zone by means of multiple exposures of two minutes on the same plate. Further, each zone was similarly connected at six equi-distant points with the Polar Sequence, which is referred to the international zero point. The connections are such as to provide a series of adjustment conditions, similar to those existing in a triangulation net, which was used in reducing the results to a homogeneous system. Although the Polar Sequence is the standard for the zero point of the Catalogue, the magnitude scale has been independently derived for each Area with the aid of the diaphragm and screen exposures. The resulting mean scale for the Catalogue is, however, identical with that of the Polar Sequence, and hence, with the international photographic scale adopted at the Rome Conference of the International Astronomical Union in 1922. This is shown by the intercomparison photographs for the 37 Areas connected directly with the Pole, which give the following mean differences in magnitude:

Magnitude	11.5	12.5	13.5	14.5	15.5	>16
Difference	0.00	-0.01	0.00	0.00	0.00	-0.01
No. Stars	58	181	398	528	400	52

The measurement and reduction of the long-exposure photographs were made at Groningen as originally planned. All the other plates, both diaphragm and intercomparison, were measured and reduced at Mount Wilson.

The combination of the two series of measures and the preparation of the manuscript for the Catalogue were also done at Mount Wilson.

The Catalogue, which appears under the names of Seares, Kapteyn and van Rhijn, with Miss Joyner and Miss Richmond as assistants, gives the photographic magnitudes, number of individual observations and approximate co-ordinates of 67,941 stars. The results are arranged in the serial order of the Areas, those for each Area being divided between a main list, which gives the mean magnitude of all the stars in the fields adopted at Groningen, and a supplementary list, which includes stars outside the Groningen fields and hence measured only at Mount Wilson. The fields for the main lists are 15' by 15' for galactic latitudes less than 40°, and 20' by 20' in higher latitudes.

The limiting magnitude varies considerably from Area to Area, but averages about 18.5. The inclusion of exposures with 9- and 14-inch diaphragms has made it possible to measure, with very few exceptions, even the brightest stars within the limits of the adopted fields. Results for stars brighter than the tenth magnitude are, however, of low weight; and, since the fields are small, the Catalogue is useful for statistical investigations only for stars fainter than the thirteenth or fourteenth magnitudes.

The precision of the catalogue magnitudes varies between rather wide limits, chiefly because of the difference in the number of observations for individual stars. For stars of intermediate brightness having measurable images for all of the exposures, the number of separate determinations is 16; at the other extreme are the faint stars visible only on the plate of 60-minutes exposure, for which only single values are available. The average probable errors, including zero-point uncertainty, are approximately as follows:

No. Observations	1	3	5	7	9	11	13	15
Probable Errors	±0.157	0.086	0.070	0.063	0.059	0.057	0.055	0.054

The Catalogue provides numerous standards, well distributed over the sky, for use in determining the magnitudes of faint stars in neighboring regions. At the same time, the photometric data included in the Catalogue itself are so extensive as to permit an immediate discussion of some of the problems of stellar distribution in a manner not hitherto possible. In fact, these investigations, which were begun long before the data for the Catalogue were finally assembled, are complete and in print, and have been fully described in the reports for the two preceding years.

STELLAR SPECTROSCOPY

The use of the 15-foot autocollimating prismatic spectrograph at the coudé focus of the 100-inch reflector was continued throughout the summer and autumn of 1927. In November, however, the definition with the 6-inch lens deteriorated greatly, and it was returned to J. W. Fecker at Allegheny for investigation. It was found that the glass of one of the component lenses had become affected seriously, and a new lens was made to replace it. The entire combination was recentered and mounted in a new cell. Tests made since the return of the lens indicate satisfactory performance.

The spectrograms obtained with this instrument have proved of such value for physical studies of spectra and accurate determinations of radial velocity and differential displacements of lines that it has seemed desirable to adapt the spectrograph for use on fainter stars. Accordingly, a 4-inch lens of the Ross type with a focal length of 9 feet has been obtained and will be mounted in the axis of the 15-foot spectrograph. A rack is provided for moving the 9-foot lens to one side when the larger instrument is employed. This 9-foot spectrograph may be used either in the autocollimating form or with cameras of shorter focal length in conjunction with the single prism. A gain of one magnitude is to be expected from the use of the 9-foot as compared with the 15-foot spectrograph.

A new plane-grating spectrograph of aluminum and steel construction was completed in May and has been used with excellent success by Merrill and Sanford. The dispersion piece is a grating ruled by Jacomini, and the collimator is a lens of the telephoto type, designed and constructed especially for the purpose by the Bausch and Lomb Optical Company. The instrument was planned particularly for observations in the red and near infrared portions of stellar spectra. With a 10-inch camera giving a linear dispersion of 65 Å to the millimeter, spectra of eighth magnitude N-type stars have been photographed as far as λ 6600, and in bright stars the calcium triplet near λ 8500 has been obtained without difficulty.

The stellar spectroscopic observations during the year have been carried on by Adams, M. L. Humason, Joy, Merrill, Sanford and Strömberg of the regular staff, while Dr. Dunham and Dr. Leonard have taken part in special investigations. A total of 1,339 spectrograms has been secured with the Cassegrain spectrographs, of which 862 were made with the 60-inch, and 537 with the 100-inch reflector. A large number of spectrograms taken with the 100-inch telescope are of Cepheid variables between the eighth and tenth magnitudes, visually. In addition to these, 170 spectrograms of stars fainter than the tenth visual magnitude have been made with the low-dispersion spectrograph, and 57 spectrograms of bright stars with the 15-foot spectrograph. Numerous other photographs have been obtained with the plane-grating and ultra-violet spectrographs.

RADIAL VELOCITIES

The radial velocities of about 90 stars of constant velocity have been determined from measurements of three or more spectrograms. The total number of such stars completed since the last list of published velocities from Mount Wilson is approximately 600; and the material for these additional stars is now being collected for publication. Since the recent appearance of the extensive catalogue of radial velocities from the Lick Observatory, a comparison has been made between the Lick and the Mount Wilson values for the stars observed in common. The results are as follows:

Type	No. of Stars	Mt. W.—Lick km./sec.	Type	No. of Stars	Mt. W.—Lick km./sec.
B	86	+0.51	G	74	—0.05
A	81	—0.24	K	162	+0.91
F	73	—0.52	M	58	+0.84

For the 534 stars taken together, the difference, Mt. Wilson—Lick, is $+0.34$ km./sec. Since the systematic difference in the case of the K and M stars is almost certainly due to the wave-lengths of some of the lines used on the lower-dispersion Mount Wilson spectrograms, small corrections are being applied to these lines to bring the two series into close agreement.

Among other results obtained in the course of the radial-velocity determinations the following are of interest:

(1) Unusually large radial velocities have been found for the four stars:

Boss 2425	+74 km./sec.	Cin. 2487	+76 km./sec.
Boss 4267	-75	B.D.+1°3872	-65

The first two stars are giants; the other two are dwarfs.

(2) The following variable stars show large radial velocities:

AG Aurigæ	+170 km./sec.	TU Persei	-390 km./sec.
UW Orionis	+100	SV Urs. Maj.	-95

The character of variation of these stars is such that no great range in velocity is to be expected.

Two of these stars are of exceptional interest: AG Aurigæ is usually classed as a Cepheid variable with a period of 96 days. Its spectrum varies from G to M, and its large positive velocity is very exceptional in view of its position in the sky. TU Persei is a short-period variable with a median magnitude of 11.7. Its radial velocity is among the largest known for any star. Its spectral type is A5s.

(3) Spectrograms of the Algol variables X Trianguli and RT Sculptoris have been taken at the request of Dr. Dugan for use in connection with his photometric orbits. Measurements by Joy show relative velocity displacements between the components of 210 km./sec., in the case of X Trianguli, and 260 km./sec. in that of RT Sculptoris.

(4) Sanford has completed and published investigations of the spectra and radial-velocity variations of the two Cepheid variables T Monocerotis and U Vulpeculæ, and of the cluster-type variable RR Lyræ. A similar study of the short-period Cepheid TU Cassiopeïæ is ready for publication.

(5) An investigation has also been made by Sanford of the radial velocities of the components of the eclipsing binary RX Herculis. Although the spectrum is difficult of measurement, fairly trustworthy values have been derived from 12 spectrograms obtained recently. The resulting values for the masses are in harmony with Eddington's mass-luminosity relationship. Masses determined elsewhere from scanty data had shown discordant results.

(6) The orbits of two spectroscopic binaries, each of which is a component of a visual binary, have been derived by Sanford. Both stellar systems, accordingly, are at least triple. One of these is $\Sigma 674A$, which shows a circular orbit with a period of 3.4367 days. The other is $\Sigma 1561B$, with the rather large eccentricity of 0.53 and a period of 23.5415 days.

(7) Humason has completed radial-velocity observations of all the brighter stars in the Selected Areas. The remaining stars are all between 7.5 and 9.0 in visual magnitude. During the year 78 spectrograms of these stars have been obtained with the two reflectors.

SPACE-VELOCITIES OF GIANT STARS OF SPECTRAL TYPES K3 TO K5

The velocities in space of 287 giant stars of types K3 to K5 have been investigated by Strömberg in connection with his study of their absolute magnitudes. He finds that among the super-giant stars the dispersion in velocity is small, and that these stars probably belong to the B-type star system. The solar motion as derived from the ordinary giants is 25 km./sec. in the direction $\alpha=278^\circ$, $\delta=+34^\circ$, the average peculiar radial velocity for these stars being 20 km./sec. The distribution of the space-velocities projected on the axis of preferential motion has a dispersion of 38 km./sec. and a large positive excess, but shows no trace of Kapteyn's two streams. The velocity-components projected on the axis of symmetry have practically the same numerical characteristics as those found for stars in general, for star clusters and for nebulae, thus adding a further illustration of the extremely general nature of the asymmetry in velocity-distribution.

Nine of the stars investigated may be regarded as belonging to the 61 Cygni group.

SPECTRA OF CERTAIN VARIABLE STARS

Joy has completed an extensive series of observations of the Algol variable U Sagittæ. The velocity-curve, in combination with the photometric elements of Fetaar, makes it possible to compute the absolute dimensions and the physical characteristics of the system. The mass of the fainter component, which gives out only 7 per cent of the total light, has been computed from observations during the total eclipse. The star seems to be a typical giant of type G2 with a density about one-eightieth that of the sun. Its diameter had been calculated from the rotational effect, which is marked during partial eclipse. Orbits and absolute dimensions have also been derived by Joy for RT Lacertæ and RS Canum Venaticorum. Both stars show spectra with double lines.

A spectrogram of RT Serpentis taken by Joy on June 26 shows strong bright lines of hydrogen and numerous emission lines of ionized iron. The latter include most of the forbidden lines found by Merrill in the spectra of η Carinæ and W Cephei. The continuous spectrum is relatively faint. These observations make it probable that RT Serpentis should be classed as a peculiar irregular variable with slow changes.

Joy and Sanford have continued their observations of stars of the RV Tauri type, and have completed their investigations of R Sagittæ and V Vulpeculæ. Spectrophotometric studies of these stars and of certain Cepheid variables are being undertaken for the purpose of examining the spectral changes at various phases of light.

LONG-PERIOD VARIABLES

Observations by Merrill of the bright lines in the spectra of R Hydræ, R Leonis and several other long-period variables show that in each cycle the relative intensities of certain pairs of lines change progressively in the same direction during the whole time that they are present. This is true of the pairs $H\gamma$, $H\delta$; $\lambda 4202$, $H\gamma$; $\lambda 4308$, $\lambda 4202$; $\lambda 4571$, $\lambda 4308$. For the first pair the interval of visibility includes maximum light, but $H\gamma$

gains in relative intensity both before and after maximum. This fact, with many others, indicates that the behavior of the bright lines does not depend solely on the apparent brightness of the photosphere. Systematic differences between various stars are being studied.

W Aquilæ has been found to have an S-type spectrum. The spectrum of W Ceti strongly resembles that of χ Cygni and is intermediate between classes M and S.

FORBIDDEN LINES IN STELLAR SPECTRA

Although the peculiar bright line spectrum of η Carinæ has been known for many years, a number of the strongest lines have nevertheless remained unidentified. The unknown lines have also been observed in the spectra of novæ and of several other peculiar stars. These lines have recently been identified by Merrill with forbidden lines in the ionized iron atom. They arise through transitions from metastable states at intermediate levels to the two lowest states. They have never been observed in the laboratory, but their wave-lengths are accurately calculable from the known structure of the spectrum. Low density is probably the condition which allows them to occur in the stars. Every initial state of the newly recognized transitions is the final state of well-known iron spark lines. Two curious instances of violation of the inner-quantum-number rules have been noted. Data concerning these non-laboratory iron lines should aid physicists in the study of atomic structure, particularly in the understanding of metastable states and the interpretation of the combination rules.

B-TYPE STARS WITH EMISSION LINES

About 20 additional Be stars have been discovered during the year by Merrill, Humason and Miss Burwell, and observations on other Be stars of special interest have also been continued. Their spectra have been observed with the large reflectors.

The "iron" star XX Ophiuchi and B.D. $+11^{\circ}4673$, whose spectrum contains both ordinary and forbidden lines of $Fe\ II$, have been found to exhibit interesting changes from time to time.

Bright hydrogen lines were discovered in RY Scuti at Mount Wilson in 1921. Spectrograms taken from 1921 to 1927 show a well-marked bright line in the position of the nebular line $\lambda 4658$. Four fainter lines, not previously known as nebular lines, are apparently associated with it. The spectrum of H.D. 45677 of class B2 includes numerous superposed bright lines due chiefly to hydrogen and ionized iron. Many of the iron lines are the forbidden lines recently recognized in the spectrum of η Carinæ. These two stars have much in common, but the continuous spectrum is stronger, and the forbidden lines are relatively less intense in H.D. 45677.

THE SPECTRUM OF α PERSEI

A detailed study of the spectrum of α Persei has been completed by Dr. Dunham. Approximately 1,800 lines have been measured between $\lambda 3760$ and $\lambda 6600$ on high-dispersion spectrograms, and more than 90 per cent of these have been identified. A table has been prepared giving the position and intensity of each laboratory line involved, and for most of

the lines the atomic energy levels from which they arise and the multiplets to which they belong. In the case of blends the relative contributions of two or more lines have been estimated. A list of unblended lines suitable for accurate measurements of intensity and contour is being prepared. Photometric investigations have been commenced which have for their purpose the calibration of the absolute intensities of the lines in the spectrum of the star.

SPECTRA OF DOUBLE STARS

Dr. F. C. Leonard, of the University of California at Los Angeles, has been engaged in an investigation of the spectra of the individual components of visual double stars. This work is in the nature of an extension to fainter stars of a study made at the Lick Observatory several years ago.

In the course of his observations on 35 nights, Dr. Leonard has obtained 100 spectrograms of 80 double stars with the Cassegrain and low-dispersion spectrographs. In many cases the spectra of both components were photographed on the same plate so that the total number of exposures was 143. The double stars were selected for observation on the basis of orbital motion or common proper motion of the components, so that only physically connected systems might be included.

The classification of nearly all the spectrograms has been completed, and many of them have also been used in determinations of absolute magnitude or radial velocity by members of the Observatory staff. Several notes on faint components of especial interest have been published, including one on the eleventh magnitude companion of Krüger 60, which has the spectral type M4.

Dr. Leonard has also been engaged in the compilation of a catalogue of the spectral types of all visual double stars for which the spectra of both components have been determined. This list will include several hundred stars observed at Mount Wilson. The material will be sent to Dr. Aitken, of the Lick Observatory, for inclusion in the *Extension to Burnham's General Catalogue*, now in course of preparation.

SPECTRAL CLASSIFICATION OF FAINT STARS IN THE SELECTED AREAS

Observations and determinations of spectral types of the faint stars in 12 of the Selected Areas have been completed by Humason during the year. Of the 115 areas under investigation 84 are now finished. The remaining 31 areas are for the most part north of $+30^\circ$ declination.

DETERMINATIONS OF LUMINOSITY AND PARALLAX

The classification of the spectra of all stars observed throughout the year and the derivation of their absolute magnitudes have been continued regularly by Adams, Joy and Humason. Special attention has been given to stars of types K3 to K8, about 400 of which, including both giants and dwarfs, have now been investigated. Strömberg has made a study of 287 giants among these stars, applying to them the formulæ for computing the absolute magnitudes by the aid of peculiar and parallactic motions. Twenty-eight of the stars may be considered as super-giants and have a mean absolute magnitude of -1.4 . The remaining stars have a mean magnitude

of -0.1 , with a dispersion of 1.3 mag. These stars, accordingly, resemble those of type M in showing but a small range in the absolute magnitude derived by the spectroscopic method. The probable error of the determinations is slightly less than 0.6 mag.

The absolute magnitudes of several faint components of stars of large trigonometric parallax have been derived from spectral observations. Among these are the companions of τ Boötis, 5 Serpentis and β Aquilæ. The results indicate a satisfactory agreement with the correlation established previously between absolute magnitude and spectral subdivision among dwarf M stars. An interesting pair of dwarf Me stars of common proper motion was brought to our attention by Dr. Shapley. These are H.D. 196982 and H.D. 197981. Our observations showed the first star to be a visual binary with each component of spectral type M3e. The spectrum of H.D. 197981 is M0e. The radial velocities of these two widely separated stars are equal within the errors of the determinations, and the absolute magnitudes indicate a parallax of the order of $0''.1$. The common proper motion of these stars was found by Dr. Luyten, who predicted a probable type of dMe for H.D. 196982.

A special investigation is in progress on the determination of the absolute magnitudes of Cepheid variables by spectroscopic methods. Spectrograms of about 80 Cepheids have been made at Mount Wilson, with the observations distributed over the period in such a way as to give the range of spectral variation. The results obtained so far indicate that satisfactory reduction tables for the Cepheids may be derived by extrapolation from the values for lines used for the ordinary giant stars of similar spectral type. The correlation of absolute magnitude with spectral type appears to be very close.

A NEW METHOD OF ANALYZING STELLAR SPECTRA

The calibration of Rowland's scale of intensities of solar spectrum lines leads to a knowledge of the relative numbers of atoms in the solar atmosphere which are active in producing different lines in the same spectral region. By assuming thermodynamic equilibrium, and that atoms at different levels are equally effective in producing a line, the investigation can be extended to stellar atmospheres in general. An equation is thus derived which connects the relative numbers of atoms producing the same line in different stars with the relative numbers of normal neutral atoms, the excitation potential, the state of ionization, and the electron pressures and temperatures in the stars.

The spectrograms of typical stars taken at the coudé focus of the 100-inch reflector have been utilized by Adams and Russell in an investigation of this character. The great linear scale of the photographs and the large extent of spectrum covered make it possible to select many lines of different elements which originate in successive spectroscopic terms. The intensities of these lines have been estimated on Rowland's scale by means of a standard solar spectrum photographed with the same instrument, and these intensities have then been calibrated and arranged in groups according to excitation potential.

The principal results found in the course of this preliminary investigation are as follows:

(1) There appears to be a serious and widespread departure from thermodynamic equilibrium in stellar atmospheres, which has the result that the relative number of atoms in excited states, especially those of high energy, is much greater than that indicated by theory. The well-known behavior of the hydrogen lines in giant stars appears to be a particular instance of the phenomenon.

(2) The anomaly does not appear to affect ionization, at least to any such degree as it does excitation.

(3) An empirical method of correction for the effects of this anomaly has been developed, which leads to a new method of determining stellar temperatures. The temperatures thus found for stars of types M to A are given below. The effective temperature, T_e , of the sun's photosphere is taken at 6000°C. , and that of the atmosphere, following Eddington, at $0.88 T_e$, or 5300°C.

Star	Spectrum	Atmosphere	Photosphere	Star	Spectrum	Atmosphere	Photosphere
α Orionis...	cM2	2520	2900	(Sun).....	dG0	(5300)	(6000)
α Scorpii...	cM1	2620	3000	α Persei....	cF5	5940	6700
α Boötis....	gK0	3380	3850	α Can. Min.	cF4	6900	7850
γ Cygni.....	cF8	4950	5600	α Can. Maj.	A2s	8700	9900

These values are in excellent agreement with the accepted scale of temperatures derived by other methods.

(4) The strength of the enhanced lines in the red giants suggests that they are produced largely in extensive chromospheres supported by radiation pressure.

(5) The amount of metallic vapor above equal areas of the photosphere in the cooler c-stars (α Orionis, α Scorpii, γ Cygni) seems to be of the order of 100 times as great as in the sun; and in α Boötis and α Persei about 10 times as great. The amount in Procyon is comparable with that in the sun, and that in Sirius, smaller. On account of higher ionization in Sirius the amount can not be estimated closely.

(6) These results are in fair agreement with the existing theory of the production of a photosphere by general opacity in atmospheres of similar composition. It seems probable that in the atmosphere of Sirius the metallic vapors are diluted by some other constituent, possibly hydrogen.

STELLAR RADIATION

Most of the work on stellar radiation by Pettit and Nicholson during the past year has consisted in the reduction of all the measurements to date and their preparation for publication. This has included the derivation of the radiometric magnitude, heat-index and water-cell absorption for 124 stars, a determination of the total radiation reaching the solar system, and a computation of the absolute bolometric magnitude of each star. The temperatures and diameters obtained from these data are given for a

selected list of stars of exceptional interest. Both Betelgeuse and Antares are found to be brighter radiometrically than Sirius, which is followed by Canopus and γ Crucis. The values for the last two stars were obtained by inference from the plot of heat-index against spectral type.

Distinct dwarf branches beginning at F5 and ending at K2 are found when the spectral type is plotted against either heat-index or water-cell absorption. The plot of heat-index against water-cell absorption is a smooth curve, which for temperatures lower than 2700° absolute deviates appreciably from the curve computed from the formula for a black body, the known transmission, and the adopted visual sensibility curve. This would apparently indicate that stars of low temperature do not radiate like black bodies. The stars of type N, however, fall close to the computed curve, while long-period variables of the same temperature (about 2200° absolute) deviate from it by about 2.5 magnitudes in heat-index, and 0.4 magnitude in water-cell absorption.

A new intercomparison of the standards used to determine the constant of radiation for a star of 0.0 radiometric magnitude gave the value 17.3×10^{-12} cal. cm.⁻² min.⁻¹. This corresponds to a radiometric magnitude of -20.11 for the standard candle at one meter, and of -20.00 for the Hefner lamp. The heat index of the Hefner lamp is 5.82 magnitudes, which indicates a temperature of 1900° absolute. The water-cell absorption is 2.7 magnitudes, which corresponds to 1700° absolute.

The diameters of the seven stars so far measured with the interferometer are only about two-thirds as great as the values computed from the radiometric data. Since all the stars in this list are of late spectral type, their computed diameters are affected by the deviation from black-body radiation already pointed out, in the proper direction and to the approximate amount necessary to account for the discrepancy. In the list of 124 stars, the following, apart from the seven already measured with the interferometer, are some which are sufficiently bright and large to be of interest for observations with the 50-foot interferometer. The calculated diameters are given in each case:

Long-period variables at maximum: χ Cygni, 0'.041; R Cancri, 0'.022; R Leonis, 0'.047; R Aquarii A, 0'.022.

Other stars: Capella A, 0'.011; α Arietis, 0'.009; 45 Arietis, 0'.020; 19 Piscium, 0'.018.

Procyon, 0'.007, and β Ceti, 0'.007, should show a sufficient change in the visibility of the fringes to provide an estimate of the diameter.

The calculated diameter of Sirius is 0'.005. Sirius is found to have an abnormal heat-index, which may be explained as due to a faulty visual magnitude. Its water-cell absorption, however, is normal. The sun is another star showing the same peculiarity.

A new reduction of the mean absolute bolometric magnitude of the long-period variables, including all available material, gives a value of -3.2 . According to Shapley's period-luminosity diagrams, this corresponds to the luminosity of a Cepheid variable having a period of about 10 days.

THE TWENTY-FOOT STELLAR INTERFEROMETER

A few additional stars have been examined by Pease with the 20-foot interferometer, and measures of Betelgeuse have been continued when conditions allowed. The best determinations were made on February 26, 1928, when the fringes were found to disappear for a separation of the mirrors of 12.7 feet. This corresponds to a diameter of 0'.037 for the star.

LABORATORY INVESTIGATIONS

SPECTRA OF RARE EARTHS

Much of the work of King in the Physical Laboratory has consisted in a study of the spectra of several of the rare earths. Photographs have been made of the spectra of cerium, praseodymium, neodymium and samarium in the electric furnace, with comparison spectra of the same elements in the arc and spark. Occasionally iron has been added to the mixture in the furnace to facilitate wave-length measurements, and cesium has been used frequently to assist in separating the lines of the neutral from those of the ionized element. As is well known, the lines due to the ionized atom are suppressed when an element of lower ionization potential is introduced into the furnace tube. This method has proved most useful in deciding cases in which the usual comparison of arc and spark spectra proves insufficient. A peculiarity of these rare-earth spectra is that the neutral lines of short wave-length are faint in the arc, and often obscured by blends with enhanced lines. Since the furnace at low temperatures gives a pure spectrum of the neutral atom, many lines have been measured in the furnace spectra.

The procedure followed in the study of these spectra has been to select from among the thousands of lines present those which are strongest and most distinctive of the ionized and neutral atom, and hence most likely to appear in the spectra of the sun or stars. For all such lines the temperature classification by means of the furnace affords material for analysis according to relative energy-levels. Of especial interest for the purpose of series classification are the lines of the neutral atom which are persistent at low temperatures, and those of the ionized atom whose appearance in the furnace, sometimes at moderate temperatures, marks them as of low energy-level.

The ease of production of enhanced lines in the furnace should increase for elements of successively lower ionization potential. This is confirmed by observation. Praseodymium, with an ionization potential near that of lanthanum, resembles it in the readiness with which the lines of the ionized element appear in the furnace. Cerium, on the other hand, although of intermediate atomic number, has a much higher ionization potential, and the enhanced lines are correspondingly difficult of production.

A further study has been made of the ultra-violet spark spectrum of the doubly-ionized atom of each of these elements. In every case the doubly-ionized spectrum is found to show a group of very strong lines near its long wave-length limit. The mean position of this group moves toward shorter wave-lengths as the ionization potential increases, in the order, praseodymium, neodymium, samarium, cerium.

As previously noted by King, a large proportion of the lines of praseodymium are complex. Many of these have been examined with the 30-foot spectrograph and can be resolved into several varieties as regards the number and spacing of the individual components. This characteristic may be expected to aid in their series classification, since there is a clear tendency for lines of similar structure to group in the same region of the spectrum.

As a result of these investigations, 1,362 lines between λ 3000 and λ 7000 selected from the cerium spectrum, and 1,018 from that of praseodymium have been assigned either to the neutral or ionized spectrum, and have been classified according to temperature. About 40 per cent of the praseodymium lines are complex in structure. Although the classification of the neodymium and samarium lines is incomplete, enough material has been supplied for the identification of these elements in solar and flash spectra.

SPECTRA OF OTHER ELEMENTS

King has also made a study of the principal neutral and enhanced lines of erbium, and has made ultra-violet arc and spark spectrograms of columbium, iron, nickel, yttrium and tungsten. Photographs of the spectrum of bismuth have been obtained to show the character of the fine-structure of its lines, as well as low-temperature absorption spectrograms of sodium to decide the relative levels of neutral lines in the ultra-violet. Furnace, arc and vacuum-arc spectra of boron have been used in a search for predicted lines, and high-dispersion photographs of the band spectrum of boron have been supplied to Nicholson and Perrakis for comparison with sun-spot spectra. In this way the presence of boron bands in the sun-spot spectrum has been established.

PRESSURE EFFECT FOR IRON

The investigation of the effect of pressure on lines of the iron spectrum has been continued by Babcock, and the results so far obtained have been published. These may be summarized in two empirical equations which give, for spectral terms of different multiplicity, the change of level produced by a difference of one atmosphere in the pressure at the source of light. A simple calculation from these equations gives the corresponding displacement in wave-length of any iron line which has been assigned a place in a multiplet. Comparison with the work of Gale and Adams for both iron and titanium shows a close qualitative agreement. The Mount Wilson classification of iron lines has been given a definite numerical description which increases its usefulness; and the temperature classes assigned by King to the lines of numerous elements have been examined statistically with relation to the levels of the terms involved. From this it appears that in general a progression of one temperature class corresponds to an increase of about 0.7 volt in the excitation potential. In the case of calcium, however, the amount is about 0.35 volt.

STANDARDS OF WAVE-LENGTH

Babcock has now collected and published the results of his measurements made during previous years on standards in the spectra of iron and neon.

These show very satisfactory agreement with the work of other laboratories. The visible and near ultra-violet regions are now well supplied with standards, but further observations are needed in the infra-red and ultra-violet.

Babcock has devoted much time to the compilation of the triennial report of the Commission on Standards of Wave-lengths and Tables of the Solar Spectrum of the International Astronomical Union. In this report it has been found possible to present to the Union an improved system of 259 secondary standards in the spectra of neon and iron between λ 3370 and λ 6750; some tentative standards of shorter wave-length; a new system of solar standards on the same scale, consisting of 352 lines between λ 3592 and λ 7122; selected lists of lines suitable for extending these systems; and numerous other wave-lengths, of great value, but not sufficiently well established to be recommended for adoption as standards. The recommendation is made to the Union that it adopt a system of standards in the far ultra-violet consistent with those in use in the region of longer wave-length.

CONTINUOUS SPECTRA FROM VACUUM TUBES

Several years ago it was noticed that a strong continuous background is shown by vacuum tubes through which a heavily condensed discharge is passed. The vacuum tube used in these experiments had an internal diameter of 8 mm. and a length of 15 cm., the discharge being taken from a one-microfarad condenser charged to approximately 15,000 volts. Since then this method has been employed by Lyman and others for producing continuous spectra in the Schumann region of the spectrum.

During the past year Anderson has made a preliminary study of this method, hoping to learn something about the origin and general characteristics of this continuous spectrum. Various tubes have been used with the 2-microfarad condenser, charged to voltages ranging from about 3,000 up to 35,000 volts. As a result maximum current densities of from 3,000 to about 3,000,000 amperes per square centimeter were obtained, the initial pressure of the gas in the tubes being approximately 0.5 mm. of mercury. The experiments show that if the current density is less than about 10,000 amperes per square centimeter, the continuous spectrum is practically absent. It increases very rapidly with the current density above this value, and at 20,000 amperes per square centimeter it is very strong indeed as seen in an end-on tube 10 cm. long. With this length of tube the increase in intensity at higher current densities is slight, indicating that 20,000 amperes per square centimeter may be regarded as a sort of "saturation" value for this length of tube. With shorter tubes, or better with the tube 1 cm. in diameter viewed side-on, a similar saturation value is indicated somewhat above 30,000 amperes per square centimeter. Tubes as small as 1 mm. in diameter have been used, and for these, still higher saturation values are indicated, but their actual determination is somewhat laborious because the tubes very often break into small fragments if too high a value of the current is chosen. Consequently this part of the investigation is still unfinished.

The existence of these saturation values is significant for reasons evident from the following example: Consider two tubes, one 10 cm. and the other

1 cm. in length. Let a discharge of say 35,000 amperes per square centimeter be passed through each of them. From what has been said it follows that, viewed end-on, they will both appear to have sensibly the same brightness. Hence in the case of the 10-cm. tube nearly all the light which reaches the observer must originate in the 1 cm. of its length nearest the observer's eye; and since it is clear that the other 9 cm. are emitting light in all directions, it follows that nearly all the light emitted by them in the direction toward the observer must be absorbed by the last centimeter of the tube. In other words, a layer of the gas in such a tube, having a depth of 1 cm., is sensibly opaque to incident radiation.

This is, consequently, a method of determining the absorption coefficient of gases at high temperatures, a quantity which is of increasing interest and importance in astrophysics. The effective temperature of the gas may be measured by an analysis of its continuous spectrum. The pressure of the gas before the discharge is passed is known, and, if no additional gas were evolved by the discharge one could easily compute the pressure during the different stages of the passage of the current. Unfortunately, there is evidence of the momentary evolution of gas during the discharge, but it is hoped that some relatively simple way of evaluating this may be found.

THE SPECTRUM OF IONIZED OXYGEN

After Dr. Bowen's identification of the "nebulium" lines with forbidden lines of ionized oxygen and nitrogen, an attempt was made by Smith to produce these lines in the laboratory. It was thought that if a source rich in $O II$ and $O III$, or $N II$, could be found, the methods used by Takamine to excite forbidden lines of mercury might be applied to the production of the nebulium lines. Vacuum tubes of different forms were excited from several different transformers, a Tesla coil and a short-wave oscillation generator, with various types of condenser discharge. When the current was not too large condenser discharges through a vacuum tube with a 1-cm. capillary produced a spectrum rich in $O II$ and $O III$, but could not be made to give the lines desired. With an increase of current density, silicon from the walls of the tube became prominent. Pyrex and quartz tubes were found to behave alike in this respect.

Experiments were also tried with a discharge from an alternating potential having a very high frequency through vacuum tubes at low pressures. For this purpose a 4-meter wave vacuum-tube oscillator was constructed with an output of about 75 watts. Tubes excited in this way showed, however, no enhanced lines.

HIGH-FREQUENCY EXCITATION OF SPECTRA

The 4-meter wave oscillator has been used by Smith to obtain spectra from low-pressure vacuum tubes of oxygen, nitrogen, hydrogen, mercury, argon and iodine. The most characteristic feature, in general, is the increase in the intensities of the higher members of the various series of lines.

Under certain conditions this type of discharge exhibits a dark rift which calculation shows to be due to the effect of the electrodes on the to-and-fro motions of the electrons.

ULTRA-VIOLET RADIATION OF ARC LAMPS

Pettit, using a variety of artificial sources, has made a series of measurements of the intensity of ultra-violet radiation in the region of biological interest, λ 0.29 μ to 0.31 μ . At a distance of 1 meter the results are as follows: Therapeutic mercury arc with aluminum reflector at 400-watt consumption, 4.2 watts per square meter; same at 200-watt consumption, 1.2 watts per square meter; "C" carbon arc at 868-watt consumption, 1.0 watts per square meter. The use of an aluminum reflector practically doubles the intensity in this region, and the inverse-square law of intensity is found to hold approximately for all the reflectors tested.

The radiation from the individual lines of the spectrum of the mercury arc has also been measured and found to be only about 25 per cent of the whole radiation emitted, the hot mercury vapor contributing a large amount of infra-red radiation. The fraction of the total radiation given by this lamp in the biological region varies from 0.007 for a power consumption of 100 watts, to 0.051 for 400 watts. Above 350 watts the increase is small.

OPTICAL PROPERTIES OF FUSED AND CRYSTALLINE QUARTZ

Several fused quartz lenses, including one of 6 inches aperture and 6 feet focal length, have been made in the optical shop for investigations on ultra-violet radiation. The internal structure and optical performance of these lenses has been studied photographically by Pettit, who has used the Foucault test and microscopic enlargement of pinhole images. The results have then been compared with those given by crystalline quartz and glass lenses of similar dimensions.

All the fused quartz lenses show a reticulated structure, due probably to the fusion surfaces of the crystals used to produce the blocks of which each lens is a section. For many purposes this does not seem to interfere seriously with its optical performance, the chief effect being scattered light in the image. The 6-inch lens was found to perform about as well as a similar one made from plate glass of good quality. Another lens, however, which shows striæ similar to those occurring in bottle glass, produces multiple images similar to those given by a crystalline quartz lens of like structure. It seems probable that these striæ were present in the original quartz crystals used to make the fused block; and it is evident that crystalline quartz intended for the manufacture of fused quartz of optical quality should be selected on the basis of optical properties as well as of clearness.

PHOTOCHEMICAL CHANGES IN GLASS

Pettit has made an examination of the effect of ultra-violet light on the transmission of four sample varieties of glass, and has found in all cases a decrease in ultra-violet transmission with exposure. The specimens were placed 1 cm. from a quartz mercury-arc lamp, and the transmission was tested at intervals over a period of several days. In the case of Vitaglass a sample was tested which had been exposed to sunlight in the desert for about one year. The region of wave-length within which 50 per cent transmission occurs was found to have shifted 0.016 μ to the red, which

is about the amount produced by one day's exposure to the arc lamp. In the case of the other glasses an exposure of one day to the arc shifted the region of 50 per cent transmission to the red by the following amounts: Corex, 0.059μ ; Corning G 985 B, 0.072μ ; ordinary plate glass, 0.005μ . Heating the glasses in a smoky gas flame partially restores the original transmission.

AN OPTICAL OSCILLOGRAPH

In connection with the work on wire explosions the need has arisen for an instrument which will record variations in the current during the discharge. Smith has designed and constructed such an instrument based upon the principle that the plane of polarization of a beam of light traversing a dense medium can be rotated by a magnetic field. A similar instrument was designed by Professor Crehore about 30 years ago.

A beam of light after passing through a nicol prism, quartz plate (perpendicular to the axis), a carbon bisulphide cell, and a second nicol prism is photographed with a rotating-mirror spectrograph. The current to be studied is carried by a solenoid which surrounds the cell. The first nicol renders the light plane-polarized, the quartz plate rotates the plane of polarization, and the carbon bisulphide cell adds to, or subtracts from, the rotation, depending upon the current through the solenoid. The second nicol removes all wave-lengths from the beam which have undergone a rotation of $n\pi$, where n is an integer. Hence if the light coming through the second nicol is viewed through a spectroscope, the spectrum is seen to consist of a series of dark and bright bands, the position of the dark bands depending on the amount of current through the solenoid. If the light is photographed with a rotating-mirror spectrograph while a non-uniform current is flowing through the solenoid, the fluctuations of the current are reproduced on the film.

THE VERTICAL SEISMOMETER

The work of developing a long-period vertical seismometer has been continued by Smith, who with the assistance of Mr. Joseph Johnson, of the California Institute of Technology, has tested and selected a number of suitable springs. With this new spring the instrument has been found to be stable up to a period of swing of 23 seconds. The seismometer is now in service at a period of 12 seconds and has recorded several earthquakes.

MISCELLANEOUS INVESTIGATIONS

Several filters have been constructed and tested by Pettit which transmit principally in the infra-red. Some of these were made of selenium sputtered on glass, and at certain densities are found to show weak absorption bands in the infra-red. Several commercial filters have been investigated.

A study of the ultra-violet transmission of organic liquids of high dispersive power indicates that nearly all become opaque at about $\lambda 0.36\mu$ for an optical path 1 cm. long. An exception is toluene which transmits to $\lambda 0.30\mu$.

Pettit has also carried on some preliminary work on the construction of photo-electric cells of fused quartz for radiometric measurements in the extreme ultra-violet. Sodium and an alloy of sodium and potassium are

found to give the most promising results. Pure sodium has been produced by transfusion through glass.

THE EXPERIMENT OF ESCLANGON

In a paper by E. Esclangon, *Sur la dissymétrie optique de l'espace et les lois de la reflexion*, published in 1927, certain experiments are described which, if verified, might possibly indicate the existence of an ether drift, or that space is not isotropic. Esclangon attached inclined mirrors to a telescope in front of the objective, and sent a beam of light from the eye-end to the objective, reflecting the light back by the mirrors. He found a smaller shift in the direction of the return-beam when the telescope was pointed alternately northeast and northwest. This shift, according to Esclangon, varied with the sidereal time, and its amplitude amounted to 0'.05.

Strömberg, in cooperation with Pease, has undertaken an experiment to verify this result. Their apparatus consists of a concave mirror of 14 feet focal length, and two plane mirrors set at an angle of 45° to the beam of light, the total deviation of the beam being 180° . Light is sent through a narrow slit near the focus and is returned in the same path. In front of the concave mirror are two slits about 6 inches apart and one inch wide. The mirrors are mounted on the large turn-table floating in mercury, which has been used by Dr. Michelson in his repetition of the Michelson-Morley experiment. The position of the fringes produced by the two slits are measured with a micrometer wire as the turn-table is rotated slowly, first in one direction and then in the other.

The displacements observed during the complete rotation have been found to be small, seldom exceeding 0'.02, and do not seem to be in any way systematic. Further experiments with modified arrangements will probably be made later in the year.

DR. RUSSELL'S INVESTIGATIONS

During his stay in Pasadena, Dr. Russell devoted the greater part of his time to two investigations, which have already been described in this report. The first of these was the calibration of the scale of intensities of Rowland's solar spectrum lines, which he carried on in collaboration with Miss Moore and Adams; and the second, the application of the results to a study of the physical conditions in some of the brighter stars, in which he collaborated with Adams.

In addition to these researches Dr. Russell and Dr. Meggers of the Bureau of Standards have completed an analysis of the arc and spark spectra of yttrium, and have prepared the material for publication. Dr. Russell has also aided in the final identification of several of the elements, the presence of which in the sun has recently been established.

VELOCITY OF LIGHT

After repeated trials at a distance of 82 miles between Mount Wilson and Mount San Jacinto, Dr. Michelson decided to abandon this base-line for further investigations on the velocity of light. Haze and smoke obscured the view of the distant station so frequently that on only two occasions was it possible to see the return-beam, and then it was much too faint for measurement. The method employed—a combination of the Fizeau wheel

and the revolving mirror—should give excellent results under suitable conditions of transparency and seeing.

In June of the present year the distant station was moved to Santiago Peak, about 50 miles from Mount Wilson, and observations will be continued in the hope that sufficient light will be available for measurement. As yet, however, conditions have been very unfavorable on account of the prevalence of dust and smoke at an exceptionally high level.

Dr. Michelson has had under consideration for some years the possibility of carrying on measurements of the velocity of light in a pipe line exhausted of air. The original plan would have required a line 3 miles in length, and its almost prohibitive cost led to the decision to make further experiments on the Mount Wilson-Santiago Peak base-line. A reconsideration of the problem, however, has enabled Dr. Michelson to reduce the length of the proposed pipe-line from three miles to half a mile. This would make the project quite feasible, and the method would have the immense advantage of being independent of weather conditions, as well as of the temperature, pressure and humidity of the transmitting medium. It would also do away with the complication of extensive triangulation measurements of the distance. Dr. Michelson hopes to put this plan into execution within a relatively short time.

REPETITION OF THE MICHELSON-MORLEY EXPERIMENT

A brief reference was made in the last annual report to the repetition of this experiment by Dr. Michelson with an 11-foot steel and invar interferometer built in our instrument shop. Several hundred observations were made with this instrument by Dr. Michelson, Mr. Pearson and Pease, but no displacements of the type of those found by Professor Dayton C. Miller were detected. Calculations made by Strömberg indicate that according to Miller's results displacements of the interference fringes amounting to 0.033 of a fringe should have been found at the proper sidereal time, but no correlation with sidereal time was observed.

Residual disturbances were found, however, amounting to several hundredths of a fringe, which were ascribed to a combination of temperature effects and strains in the invar-steel structure which furnished the support for the optical parts. With a view to eliminating these difficulties, a complete alteration was made in the apparatus. The optical parts were mounted on the 100-inch cast-iron plate originally used in grinding the 100-inch disk, and this plate was floated on mercury in an annular tank and rotated by a motor. The apparatus was enclosed in a wooden room built within the main hall of the optical building, and observations were made outside the room by the light reflected upward along the axis of rotation. A series of measurements made by Pease and Pearson gave the same negative result even more decisively than the preceding preliminary work, and showed that the disturbing factors were almost completely eliminated.

The effective path of the light rays in this arrangement was about 55 feet and involved three reflections. This distance has been increased to 83 feet, and conditions have been further improved by placing the apparatus in an underground room where temperature changes are very small. The observations now in progress should result in a still higher degree of accuracy.

CONSTRUCTION DIVISION

DRAFTING AND DESIGN

The design and completion of working drawings for instruments and apparatus have been continued by Pease, Nichols and H. S. Kinney. Pease has given much study to the design of large telescopes and domes with especial reference to a 200-inch instrument, and his preliminary sketches for such a telescope have formed the basis for much of the detailed consideration given to this project during the past year.

Among the more important instruments which have been designed and for which finished drawings have been made are the following: Seven spectrohelioscopes; the vacuum spectrograph; the 9-foot coudé spectrograph; a semi-circular electromagnet; a high-speed rotating-mirror camera; the thermocouple measuring machine; the infra-red monochromator; and several portions of the 50-foot interferometer, including the outer mirror mountings, fast-motion addition to gear box, and platform and stairway.

The publications of the Observatory have required the preparation of many charts and diagrams by the members of this department.

INSTRUMENT SHOP

The work of the instrument shop has remained under the superintendence of Alden F. Ayers. The 50-foot interferometer, the spectrohelioscopes and auxiliary celostats, the new Cassegrain spectrograph for the 60-inch reflector, and the apparatus for the Michelson-Morley experiment have been the most extensive pieces of new construction during the year. Other important instruments have been the 9-foot coudé spectrograph, the infra-red monochromator, the ultra-violet drift-curve telescope, the revolving-mirror camera, the plane-grating spectrograph, instruments for the Solar Laboratory and a concave-grating spectrograph for the physical laboratory. Much small apparatus has been built for use in the optical shop and physical laboratory, and repairs and improvements to the instruments in Pasadena and on Mount Wilson have been continued as usual.

OPTICAL SHOP

In the optical shop W. L. Kinney and Dalton have made many small mirrors, lenses and prisms required in the work of the different departments. These have included 16 small mirrors and 8 four-inch lenses made by Kinney for the spectrohelioscopes, and 12 four-inch speculum plates by Dalton, which are to be ruled as diffraction gratings for the same instruments. Dalton has figured many other plane and concave speculum plates for the ruling machine, and has made several plane and concave mirrors of stellite and fused quartz. Kinney has completed the 40-inch parabolic mirror for the 50-foot interferometer, as well as two 12-inch pyrex mirrors for use in a projecting apparatus planned for making a chart of the moon.

THE RULING MACHINE

Tests of the ruling machine early in the year showed that the ruling carriage and its cross-head were insufficiently rigid. This defect had not been found earlier because its effects were confused with the errors which one by one have been eliminated. After considerable study Anderson and

Jacomini designed a new carriage, which has been constructed by Jacomini, and is now about ready for tests in the machine. The cross-head also has been largely rebuilt, strengthened and fitted most carefully to the carriage.

CONSTRUCTION AND MAINTENANCE

There has been comparatively little new construction work on Mount Wilson during the year. The change from Mount San Jacinto to Santiago Peak as the distant station for Dr. Michelson's velocity of light measurements has required a new orientation of the home station on Mount Wilson. This has been done in a simple way by swinging the long tube and house containing the 40-inch concave mirror about the pier near the front end. The apparatus and small shelters required for the distant station have been carried by trail to the summit of Santiago Peak and set in position. As in previous years, all such construction work has been in charge of George D. Jones, superintendent of construction.

A completely new system of sewage and refuse disposal has been worked out and installed for the various buildings on Mount Wilson, and repairs, painting and minor additions to the buildings have been carried on regularly. A notable gain in efficiency and convenience has come as a result of the change from the use of distillate to that of compressed gas for fuel purposes at the Monastery.

The chief construction work in Pasadena has been the remodeling of the rooms in the front of the building containing the instrument shop. Concrete floors have been laid throughout, thus greatly reducing fire risk and depreciation, and a rearrangement of the rooms has provided much better working facilities for the operation of the shop and the telephone exchange. A further improvement has been made through moving the large storehouse and transferring the wood-working department into larger and more convenient quarters. The office building has been repainted during the year, and all buildings have been kept in repair as needed.

Merritt Dowd, engineer, and Sidney Jones, assistant engineer, have maintained the operating plant on Mount Wilson. They have devoted much time to the construction and installation of mechanical and electrical equipment, and to the care of the large instruments. During the present summer all of the water storage reservoirs, with a total capacity of about 700,000 gallons, have been emptied, cleaned and refilled.

With the cooperation of the Forest Service and the Pasadena and Mount Wilson Toll Road Company, as in previous years, a fire patrolman has been maintained on Mount Wilson during the summer months. No serious forest fires have occurred in the Mount Wilson area during the past season.

THE LIBRARY

On June 30, 1928, the number of bound volumes in the library was 10,060; pamphlets numbered about 6,000, and lantern slides, about 2,000. The number of bound volumes added between July 1, 1927, and June 30, 1928, was 398, of which 131 were by purchase, 227 by binding, and 40 by gift or exchange. During the current year 110 periodicals and transactions of learned societies have been received, of which 29 are exchanges.

NUTRITION LABORATORY ¹

FRANCIS G. BENEDICT, DIRECTOR

The Nutrition Laboratory, primarily established for studying the nutrition of man, has found it advantageous in the attempts at interpretation of human nutrition studies to extend its investigations into the field of comparative physiology and to include research on animals ranging in size from the 150-gram albino rat to the 600-kg. steer. Such research has dealt particularly with the physiology of alimentation, the production and loss of heat of animals differing greatly in skin covering, and the nature of the digestive processes, the prime object being, in the last analysis, to illuminate our knowledge of the physiology of digestion and nutrition of man.

The albino rat, one of the most highly bred laboratory animals, is the standard for a great deal of nutritional work. The effects of a prolonged, one-sided diet can be studied more easily with the rat than with humans, and the short age cycle of this animal enables the determination of the effects of growth and old age over a short period of time.

The laws of heat loss and heat production when the body cells are at a low temperature can be determined only with cold-blooded animals. An extensive series of measurements already made on large snakes at the New York Zoological Park (as yet unpublished) has demonstrated that the cell temperature of these animals can be brought to that of man by raising the environmental temperature, and this research has aided materially in the interpretation of metabolism measurements on man. The unusually high body temperature of many birds makes a study (recently completed with large wild birds) of their heat production likewise helpful in indicating the influence of high cell temperature. In the last two years a well-organized colony of pigeons has also been studied, with particular reference to the crossing of various breeds and the influence of age and sex.

Ruminants offer an opportunity for studying a digestive process entirely different from that of man. The gases of fermentation, chiefly methane, and the masses of cellulose and undigested material found in the alimentary tract of the steer are not noted with animals other than ruminants. The temperature regulation of the body, the resistance to extreme changes in environmental temperature, and the laws of intermediary metabolism with ruminants are all interesting and suggestive. With the fasting steer, for example, urine analyses have shown that the chemical composition of the urine is different from that of man and other animals during the first few days of fasting, but that later, when the steer begins to live upon its own body substance, the composition of the urine more closely resembles that of other fasting animals. Even the gaseous metabolism is different with different groups of animals. Information concerning the ability of the various species of animals to withstand a prolonged fast and the nature of the metabolism during the fast, particularly in its initial stages, is there-

¹ Situated in Boston, Massachusetts.

fore important. The steer and the cow represent one of the greatest economic steps in the preparation of human food from inedible materials, such as grasses and forage. Milk production, as such, the Nutrition Laboratory has only recently begun to study, but its investigations on the physiology of the nutrition of the steer during under-nutrition, fasting, and realimentation on various standard rations throw great light upon the physiology of digestion, particularly as regards the stimulus to metabolism following the ingestion of food and the influence of the state of nutrition upon the resistance to changes in environmental temperature.

These studies have been carried out for the most part in conjunction with cooperating institutions. The Nutrition Laboratory's share in the results of these researches will be chiefly an elaboration and clarification of our knowledge concerning the physiology of the nutrition of humans, which is our ultimate goal. The dominant note in all of the investigations of the Nutrition Laboratory in the field of comparative physiology is their relation to the laws of nutrition, growth, and metabolism of man.

COOPERATING AND VISITING INVESTIGATORS

Professor E. G. Ritzman, of the Department of Animal Nutrition of the University of New Hampshire, has continued the studies in animal nutrition with particular reference, recently, to the metabolism of sheep. The liberal policy of the University of New Hampshire and the strong support given by Director John C. Kendall of the Agricultural Experiment Station have made possible material additions, reconstruction, and improvements in the laboratory at Durham, and thus this research is definitely placed upon an unusually firm footing.

Professor Lafayette B. Mendel of Yale University has cooperated extensively in a study of the metabolism of the albino rat, in that he has given us permission to install an elaborate respiration apparatus with an assistant in his laboratory. Throughout the year he has given freely of his time and counsel to the furtherance of these investigations.

Professor Hazeltene Stedman Parmenter, formerly of Mount Holyoke College, has cooperated in the preparation of reports on the physiology of exercise and the skin temperature of college students.

Dr. Howard F. Root, of the New England Deaconess Hospital, has been in regular consultation with the Laboratory staff on problems involving insensible perspiration and particularly measurements of skin temperature on pathological patients.

Dr. Oscar Riddle, of the Department of Genetics of the Carnegie Institution of Washington, has exercised general supervision of a cooperative research on the metabolism of various races of pigeons, the reconstruction of part of the laboratory, and the installation of considerable new equipment.

Professor Grace MacLeod, of Teachers College, New York City, has assisted in the preparation for publication of the material accumulated in the studies on the metabolism of the albino rat.

The extensive survey of the energy value of the food consumed by college students, initiated by Director John C. Kendall of the Agricultural Experiment Station at the University of New Hampshire, has been continued, and

many foods contained in packages or protective wrappers have been included in the study. Miss A. Gertrude Farr has these measurements in hand.

Miss Florence L. Gustafson, formerly of the Department of Physiology at Wellesley College, has completed her series of observations on the influence of season upon the metabolism of a group of college women, and the results have been prepared for publication.

Professor Samuel Brody, of the University of Missouri, spent several weeks at the Nutrition Laboratory in active association with Dr. T. M. Carpenter, studying particularly the gas-analysis technique in connection with respiration experiments on large ruminants. He also made an exhaustive study of the equipment and technique used in the cooperative research on large animals at Durham, New Hampshire.

At the request of the Rockefeller Foundation Dr. J. M. Munoz, of the Institute of Physiology, Faculty of Medicine, Buenos Aires, Argentine, was extended the courtesies of the Laboratory and has spent several weeks learning the technique of the oxy-calorimeter and the field respiration apparatus, and acquiring further experience with the Haldane gas-analysis apparatus.

Investigators who have cooperated during the past year with the Nutrition Laboratory in its studies on racial metabolism are: Professor H. G. Earle, School of Physiology, University of Hongkong, Hongkong; Morris Steggerda, Jamaica, British West Indies; O. W. Torreson, of the Department of Terrestrial Magnetism of the Carnegie Institution, but stationed at Magnetic Observatory, Huancayo, Peru; Dr. G. D. Williams, Chichen Itzá, Yucatan, Mexico; Dr. J. E. Gullberg, Rabaul, New Guinea; Professor C. S. Hicks, Department of Pathology, University of Adelaide, Adelaide, South Australia; and Dr. H. S. D. Garven, Moukden Medical College, Moukden, Manchuria. Professor Eleanor D. Mason, of the Women's Christian College, Madras, India, has spent considerable time at the Laboratory, assisting in a number of researches prior to undertaking some cooperative studies on the metabolism of students in India. Dr. L. G. Kilborn, of West China Union University, Chengtu, Szechwau, China, spent a few weeks at the Laboratory with a view of cooperating in the racial study, and acquired experience in the technique of basal metabolism measurements and especially in the use of the field respiration apparatus.

The visitors at the Laboratory are constantly increasing, and by this means we are able to render a real service to many scientific institutions. Among those visiting us the past year with a definite purpose were Doctors E. F. Du Bois of New York, A. H. Turner of Mount Holyoke College, Walter R. Miles of Stanford University, and Maurice Javillier of Paris. Stimulating conferences were also had with Doctors R. E. Frank of Breslau, Gunner Ahlgren of Upsala, H. Völker of Hamburg, T. Oda and S. Tagawa of Japan, J. Bauer of Vienna, and Claudia Petot of Paris.

There is a constantly increasing use of the Laboratory for pedagogic purposes by neighboring institutions. Groups of students from a number of institutions are shown each year through the Laboratory, and explanations of the various techniques are given by some member of the Laboratory staff.

LECTURES

Dr. T. M. Carpenter has contributed his usual lectures on basal metabolism at the Harvard Medical School. On October 31, 1927, at a joint meeting of the Sigma Xi and the American Chemical Society at the University of Missouri, he gave a lecture entitled "The Carnegie Nutrition Laboratory and its recent studies in metabolism."

The Director gave an address at Mount Holyoke College on January 21, 1928, entitled "The heat production of humans and animals and factors affecting it." A lecture entitled "Basal metabolism: The modern measure of vital activity" was given by him at the Carnegie Institution of Washington in Washington, D. C., on April 18, 1928. The same address was given at Teachers College, New York City, on April 27, 1928, and before the Atwater Club and the Department of Chemistry at Wesleyan University, Middletown, Connecticut, on the same date.

INVESTIGATIONS IN PROGRESS

Gas analysis—The extremely accurate and sensitive Carpenter gas-analysis apparatus has been studied with reference to an improved form of pipette for pyrogallie acid, the rapidity of analysis, the exact compensation for changes in temperature and the conditions necessary for its uninterrupted use. A modification of the combustion unit for the determination of methane has been adopted. The construction and analyses have been made by E. L. Fox, A. F. Sereque and Miss M. D. Finn, under the supervision of Dr. T. M. Carpenter. The use of hydrogen in the determination of oxygen by combustion has been investigated with the laboratory form of Haldane gas-analysis apparatus, and the determination of the moisture content of the air by the gasometric principle has been begun. The assembling of apparatus and the analyses have been made by A. F. Sereque.

Composition of Jerusalem artichokes—The effect of several methods of drying upon the alcohol- and water-soluble reducing and hydrolyzable sugars of the Jerusalem artichoke has been studied by Dr. T. M. Carpenter, with the assistance of E. S. Mills.

Electric automatic sampling device for ventilating air current—In sampling the ventilating air current from a respiration chamber, ideally the sample should be proportional to the total volume. With a constant flow the sample can be taken by time, but with intermittent or varying flow direct aliquoting is necessary. A small hand pump, finding extensive employment in the Nutrition Laboratory with respiration apparatus, has been used and an electric device has been constructed to draw into this pump, in direct proportion to the total volume, a sample of air for analysis. This device has been found practicable not only in the large respiration chamber for steers at Durham, New Hampshire, but likewise in that for sheep, and it bids fair to be an important addition to our technique. The technical details have been carried out by V. Coropatchinsky.

Mechanical device for rapid determination of carbon dioxide—A mechanical device, consisting of two pumps which permit the rapid determination of carbon dioxide in a ventilating stream of air, is being developed and determinations of this gas can be made with unusual rapidity and with a high degree of accuracy.

Apparatus for graphically recording the oxygen consumption and the carbon-dioxide production of humans—It is believed that the graphic registration not only of the oxygen consumption but likewise of the carbon-dioxide production, from which the respiratory quotient may be calculated, would be of great value in laboratory experiments. Efforts have therefore been directed for a number of years to developing this type of apparatus. An entirely satisfactory apparatus has not yet been secured, although definite progress has been made. The work has been carried out largely by V. Coropatchinsky.

Electric integrating meters for the compensation calorimeter—With the cooperation of the General Electric Company, particularly of B. W. St. Clair and S. C. Hoare of the Standardizing Laboratory, at West Lynn, Massachusetts, the two electric meters especially constructed for the Nutrition Laboratory by this company have undergone considerable reconstruction and readjustment prior to their extensive use in our two compensation calorimeters.

Application of a simple form of helmet to the portable respiration apparatus—To simplify the attachment of breathing appliances to the head, either in the case of normal subjects or patients, a simple form of helmet has been devised which, after much testing and adjustment, has been adapted to the portable respiration apparatus. The rubber collar at the bottom of the helmet easily fits almost any size of neck, and the junction is sufficiently tight to enable extremely accurate measurements, by graphic records, of the oxygen consumption. Its use in oxygen therapy, particularly in pneumonia, is predicted by physicians. The apparatus has been developed in large part with the assistance of E. L. Fox and Miss M. D. Finn.

Pathological studies of skin temperature—The simple method of measuring skin temperature developed at the Laboratory has been well received by a number of hospitals, and with Dr. H. F. Root at the New England Deaconess Hospital, Doctors Harvey Cushing, John Fulton, Marshall Fulton, and H. L. Alt at the Peter Bent Brigham Hospital, and Dr. Soma Weiss at the Boston City Hospital, the Nutrition Laboratory has cooperated in measurements on pathologic patients and has either loaned apparatus for such studies or has aided in the installation of apparatus purchased for the purpose by these institutions. Assistance has been given by V. Coropatchinsky and Miss M. D. Finn.

Body position and basal metabolism—In the search for ideal conditions for true basal metabolism measurements, observations were made by Miss M. D. Finn on subjects while lying on the side or in the position ordinarily assumed for sleep, as compared with lying on the back.

Digestive activity of the pigeon immediately after feeding—To study the course of the metabolism immediately after the withdrawal of food, a number of pigeons were placed, one by one, in a small respiration chamber immersed in a water bath of constant temperature. The chamber was ventilated at a slow rate and the respiratory quotient was determined at intervals for several hours after feeding, to note the time at which the fasting level of metabolism is assumed. These studies were made by Miss M. D. Finn, A. F. Sereque and E. L. Fox.

Metabolism of the albino rat—The rapid growth and easily controlled life of the albino rat make it an extremely useful animal for laboratory experiments. A research involving the use of the admirable rat colony of Professor L. B. Mendel of New Haven has therefore been begun, and a multiple chamber respiration apparatus permitting the study of four animals at the same time has been constructed and installed in the Sterling Hall of Medicine at Yale University, with a permanent assistant, Miss Kathryn Horst, in charge. This apparatus is a modification of an earlier type devised in the Nutrition Laboratory, and although intended primarily for the determination of the oxygen consumption alone, also permits measurement of the carbon-dioxide production and hence determination of the respiratory quotient. Prior to its installation in New Haven a great deal of time was devoted by V. Coropatchinsky and Miss M. D. Finn to testing it by alcohol check experiments, in which the amount of alcohol burned should represent the carbon-dioxide production and oxygen consumption of an animal as small as the rat. These tests were finally successful. The effects of fasting, of environmental temperature, and of the huddling of a group of rats as compared with an individual rat, have been studied and particular attention is to be given to the influence of various special diets involving either unusually rapid growth or stunting. It is expected that these studies will throw considerable light not only upon the life history of the rat but more especially upon the correlation between the metabolic activity and the various types of diet and various rates of growth which can be arbitrarily imposed upon these animals. The work has been carried out with frequent conferences with Professor L. B. Mendel.

Metabolism of pigeons—An exact duplicate of the multiple chamber respiration apparatus for rats was exhibited at the Carnegie Institution of Washington in December 1927, and its flexibility was demonstrated by having in the four chambers, respectively, a white rat, a ring-neck turtle-dove, a day old chick and a small alligator. After the exhibit the apparatus was sent to the Department of Genetics at Cold Spring Harbor, where it is now installed for the study of the metabolism of the pigeon. After a great deal of preliminary study, in which the extreme lability of the metabolism of these birds has at times baffled us considerably, a definite routine has been established, involving for the most part night work, and the multiple chamber respiration apparatus exhibited at Washington is being regularly employed for studying four birds at the same time under optimum conditions of temperature and after withdrawal of food. The apparatus is adapted not only for small ring-neck turtledoves but likewise for common pigeons. The major changes in the experimental routine are that all measurements are made at a temperature of about 28° C. and during the night. The apparatus is designed primarily for oxygen measurements alone, but an absorption train has been attached to two of the four chambers to permit carbon-dioxide measurements for the determination of the respiratory quotient. The research has been under the direct supervision of Dr. Oscar Riddle and the experiments have been made by Miss Edith Banta.

Metabolism of large ruminants—The successful series of experiments with steers accomplished by Professor E. G. Ritzman has resulted in the

publication of two monographs and the accumulation of a large amount of material as yet unpublished. But this long series of experiments so taxed the original large respiration chamber that it has been necessary to reconstruct it completely. In so doing Professor Ritzman included a new device for the separation and the collection of feces and urine from cows while inside the respiration chamber. At the same time the University of New Hampshire has rebuilt the laboratory, so that now the building and apparatus represent practically a completely new equipment. The rebuilding and testing of the large chamber, the readjustment of weights and balance, the installation of new gas-analysis apparatus with modifications to simplify its use, have involved a good part of the time of a number of the Nutrition Laboratory staff, particularly of E. L. Fox, V. Coropatchinsky and Miss M. D. Finn.

Metabolism of sheep—The necessity for almost completely demolishing the large respiration chamber for steers made it especially advantageous that two special respiration chambers for sheep were available, for experiments could still be carried on with a smaller ruminant. Special emphasis was laid this last winter upon studying the metabolism of sheep at greatly different environmental temperatures. One chamber was small enough to accommodate a single lamb up to six weeks of age. Mature sheep were studied in 5-hour periods on three consecutive days, immediately after feeding, and 24 and 48 hours after feed. Suckling lambs can not well fast over four hours. Hence the lamb was left in the chamber for but two or three hours. It was then taken out, given a bottle of milk, and put back into the chamber for another three hours. Fifty-eight experiments with sheep of various sizes were thus carried out by Professor Ritzman, aided by A. D. Littlehale and Miss H. M. Hilton. This equipment for sheep has proved most satisfactory, and Professor T. Brailsford Robertson of the University of Adelaide, Adelaide, South Australia, has had the equipment duplicated by our former mechanic, Mr. W. E. Collins. The Nutrition Laboratory has overseen the entire construction of this apparatus, has calibrated it, and rendered every possible assistance to Professor Robertson to enable him to secure a satisfactory, well-functioning apparatus.

A study of the energy value of the food eaten by college students—Employing the Nutrition Laboratory's oxy-calorimeter at the University of New Hampshire, Miss A. Gertrude Farr has been continuing her study of the energy value of the portions of food served at the College Commons and at various eating establishments in Durham and nearby New Hampshire cities, with special reference to many of the foods put up in packages, such as sandwiches, candies, etc. The energy determinations were made at Durham, and the nitrogen determinations were made by Miss Farr at the Nutrition Laboratory. Photographs to indicate the size of each portion for comparative purposes have also been taken.

Racial metabolism—One of the major activities of the Nutrition Laboratory the past year has been the training of co-workers in the racial metabolism studies in the use of the field respiration apparatus (devised here), the giving of advice to co-workers while in the field, and the calculation and verification of the results of the metabolism measurements. Two studies

have already been completed and the manuscripts reporting the results are ready for the printer. O. W. Torreson has returned from the Huancayo Magnetic Observatory in Peru, and the field apparatus there has been left in the hands of P. G. Ledig, who is continuing the collection of data in that locality. A complete equipment has been placed on the non-magnetic yacht *Carnegie*, in charge of Captain J. P. Ault, O. W. Torreson and Dr. J. H. Paul, who will make metabolism measurements on members of the crew on the yacht during their survey of the oceans. Apparatus for racial studies have also been supplied for use in the field to Dr. L. G. Kilborn of West China Union University and Professor Eleanor D. Mason of the Women's Christian College, Madras, India. No one cooperative venture of the Nutrition Laboratory has attracted such general attention as has this, and although it is too early to predict any startling outcome, it is already seen that such investigations are most helpful in adding to our knowledge of the physiology of the various races studied.

APPARATUS DONATED TO SCIENTIFIC INSTITUTIONS

On recommendation of the Director, a respiration apparatus formerly used by the Nutrition Laboratory for studying the metabolism of infants was presented, through President Merriam, to the Hôpital des Enfants-Malades in Paris for researches under the direction of Professor W. Nobécourt and particularly Dr. Henri Janet.

As a result of her sojourn at the Nutrition Laboratory a considerable amount of respiration apparatus was loaned to Professor Eleanor D. Mason for cooperative studies on the students in Madras, India, and several pieces of respiration apparatus for pedagogic purposes were donated to the Women's Christian College at Madras to further studies on the metabolism of races.

A former research associate of the Institution, Professor E. P. Cathcart of the University of Glasgow, has been much interested in the new gas-analysis apparatus of Dr. Carpenter, and a carefully calibrated burette essential to this apparatus has been presented to the Department of Physiology of the University of Glasgow.

EDITORIAL WORK

An unusual amount of time this year was spent on editorial work, not only in the preparation of material now printed and cited in the following list of publications, but in the preparation of a number of other articles as yet unprinted, although many of them are in press. Among these is a series of seven articles on various factors affecting basal metabolism, prepared at the time of closing this report (June 30, 1928) and about to appear in the *American Journal of Physiology*. The titles of these are as follows:

Basal metabolism data on normal men and women (Series II).

The basal metabolism of some browns and blacks in Jamaica (with Morris Steggerda).

The basal metabolism of Mayas in Yucatan (with G. D. Williams).

Age and the basal metabolism of adults.

Basal metabolism before and after a summer vacation.

The seasonal variation in basal metabolism (with Florence L. Gustafson).

Normal menstruation and gaseous metabolism.

Three articles dealing with the elaboration of certain laboratory techniques are also in type for publication in a German Handbook (Abderhalden) the titles of which are (1) *Ein einfacher adiabatischer Calorimeter zur Bestimmung der Energiewerte von Brennstoffen, Nahrungsmitteln und Exkreten*; (2) *Der Oxycalorimeter: Eine Methode zur Bestimmung der Verbrennungswärme von organischen Substanzen*; and (3) *Ein transportabler Respirationsapparat für medizinische, anthropologische und andere wissenschaftliche Expeditionen*.

A description of "The measurement of skin temperature" for publication in English in an Amerikaband of the Halle Academy of Science is already in galley proof, and a report on *Human Skin Temperature as affected by Muscular Activity, Exposure to Cold, and Wind Movement*" (with Hazelene S. Parmenter) is practically ready for the printer.

Dr. T. M. Carpenter has prepared an article entitled *Control Tests of a Haldane Chamber Apparatus in the Metabolic Study of Adult Alcoholized Poultry*, which is to appear in the Journal of Laboratory and Clinical Medicine.

A bibliography of some 800 titles on the physiology of exercise and muscular work was prepared with the volunteer assistance of Mrs. E. B. Leith. Two copies of this bibliography have been bound in typewritten form for library use, and one copy has been presented to the Carnegie Foundation for the Advancement of Teaching. The general interest in the physiology of exercise, particularly in relation to athletic studies, has led to a number of conferences between the Director and Dr. H. J. Savage and Dr. D. F. Smiley of the Carnegie Foundation and President F. P. Keppel of the Carnegie Corporation of New York.

Miss E. A. Wilson has had charge of most of this editorial work.

PUBLICATIONS

- (1) *Perspiratio insensibilis: Ihr Wesen und ihre Ursachen*. Francis G. Benedict and Cornelia Golay Benedict. Biochem. Zeitschr., vol. 186, pp. 278-312 (1927).

An extensive review is given of the literature dealing with insensible perspiration, followed by a description of the special technique employed by the Nutrition Laboratory, which enables the measurement of the total insensible loss, the separation of the losses from the lungs and skin and an analysis of the loss from the lungs. With normal resting individuals the total insensible perspiration is between 20 and 40 grams per hour. The skin loss represents approximately 50 per cent of this total loss and consists chiefly of water. With a normal woman, accustomed to exposure to cold, both the total loss and the skin loss were practically uninfluenced by the removal of clothing or by the blast of air from a powerful electric fan. The insensible loss through the lungs represents likewise about 50 per cent of the total loss. Since 75 per cent of the loss through the lungs is water, 87.5 per cent of the total insensible perspiration from the body can be considered to be water from the skin and lungs.

- (2) *The gaseous metabolism of large wild birds under aviary life.* Francis G. Benedict and Edward L. Fox. Bicentenary Number Proc. Am. Philos. Soc., vol. 66, pp. 511-534 (1927).

At the New York Zoological Park the gaseous metabolism of large wild birds was studied with a closed-circuit respiration chamber, enabling measurements of the carbon-dioxide production and the oxygen consumption. The birds, twenty-four in number, were full grown and ranged in weight from a 17-kg. cassowary to a 600-gram American bittern. The results, reported in terms of heat production, are based upon the minimum values obtained during periods of muscular repose, usually 28 hours or more after food, and at a controlled environmental temperature of about 19° C. The rectal temperature averaged about 40° C. The respiratory quotient was between 0.72 and 0.74. The 24-hour total heat production ranged from 516 calories with the 17-kg. cassowary to 56 calories with the 600-gram American bittern, varying in general with the size of the bird. The heat production per kilogram of body weight was inversely proportional to the size of the bird, although there were some marked exceptions to this general rule. The heat production per square meter of body surface per 24 hours averaged 874 calories. The range was from 526 calories with the Chilean sea eagle to 1,267 calories with the black-backed pelican. The only explanation found for the wide difference in these values is that these birds represent two entirely different heat-producing organisms, in which the surface area is without the slightest significance.

- (3) *A "field respiration apparatus" for a medical and physiological survey of racial metabolism.* Francis G. Benedict. Boston Med. and Surg. Journ., vol. 197, pp. 1161-1175 (1927).

A small, light-weight respiration apparatus, permitting the accurate measurement of the oxygen consumption of humans, has been developed for use, particularly in studying the metabolism of remote races. In principle it is the same as the student respiration apparatus of Benedict and Benedict. The subject breathes with a rubber mouthpiece connected through two simple valves with a closed circuit of oxygen-rich air. This closed circuit consists of a metal can, partly filled with soda-lime for the absorption of the carbon dioxide produced, and covered with a light-weight rubber bathing cap for the expansion and contraction of the air during respiration. The oxygen consumed is replaced by oxygen from a rubber bag (basket-ball bladder). This oxygen is saturated with water vapor and is then metered through a hand pump delivering a known and constant volume per stroke. The experiment begins and ends with the bathing cap at a definite degree of distension, and the oxygen introduced during the experiment is thus a measure of the oxygen consumed by the subject. Details are given regarding the technique of conducting an experiment with this apparatus, the tests for tightness, the calibration of the pump, and the method of calculating the results. The apparatus has been so simplified and standardized that it enables the determination of the oxygen consumption of an individual with but one major measurement, *i.e.*, the time required for the absorption of six pumpfuls of oxygen.

- (4) *Note on the changes in composition of compressed air after long storage in a steel cylinder.* Arthur F. Sereque. Journ. Am. Chem. Soc., vol. 50, p. 419 (1928). -

Analyses of compressed air, originally used in testing delicate gas-analysis apparatus, after seventeen years' storage in a steel cylinder gave evidence

of a slight drop in carbon-dioxide percentage and a drop of approximately 0.6 per cent in oxygen content.

- (5) *The energy metabolism of women while ascending or descending stairs.* Francis G. Benedict and Hazelten Stedman Parmenter. *Am. Journ. Physiol.*, vol. 84, pp. 675-698 (1928).

With twelve young women at Mount Holyoke College the oxygen consumption was studied during horizontal walking and during the ascent and descent of stairs. The respiration apparatus employed was designed especially to be carried in larger part by the operator rather than by the subject. The optimum rate of walking was found to be at about 65 meters per minute, the total heat production per horizontal kilogrammeter at this rate averaging 0.79 gram calorie. During the ascent of stairs at the rate of 72 to 92 steps per minute, the total energy expenditure per vertical kilogrammeter averaged, respectively, 8.8 and 8.4 calories *after a standing start* and 10.7 calories *after a walking start*. It therefore costs from ten to thirteen times as much to ascend a vertical distance of one meter as to walk horizontally the same distance. Correction for the period of transition from the standing to the climbing level of metabolism, made in a few instances by measurement of the after-effect of the exercise, raised the average total energy expenditure per vertical kilogrammeter to about 12.2 calories. In the ascent of a mountain stairway (an unbroken flight of 522 steps) a preliminary climb of at least 130 steps ruled out the effect of the transitional period. Under these conditions the total heat production per vertical kilogrammeter averaged 12 calories or fifteen times the energy expended per horizontal kilogrammeter in walking on the level at the rate of about 2 or 2.5 miles per hour. The increment in heat production (*i. e.*, deducting the energy involved in standing and in forward progression) amounted to about 9.3 calories per vertical kilogrammeter. From this increment and the known calorie equivalent of a vertical kilogrammeter, the mechanical efficiency of these women in vertical lift was computed to be 25 per cent, surprisingly close to that found with men in spite of the difference in gait. Descent of the mountain stairway required an energy expenditure of 3.9 calories per vertical kilogrammeter or about 33 per cent of that needed in ascent. The increment in heat due to the work of descent was 1.9 calories per vertical kilogrammeter. For practical purposes it can be considered that the average person expends the same amount of energy in walking up one flight of stairs as he does in walking on a level fifteen times the distance represented by the vertical height of such a staircase, or in descending three such flights.

- (6) *Basal metabolism in anthropology.* Francis G. Benedict. *Chinese Journ. Physiol.*, Report Series, No. 1, pp. 33-38 (1928).

Knowledge of the basal metabolism, first measured in the laboratory because of its physiological importance, has become of great value in pathology, and normal standards have been established enabling the comparison of the pathologic with the normal individual. Measurements on young women students in two different colleges in the United States have indicated that the basal metabolism of the Oriental women was about 10 per cent below that of the commonly accepted standards for American women. The Carnegie Institution of Washington has appropriated funds making possible cooperative researches, and a special apparatus has been

devised and placed in the hands of several field workers. Basal metabolism measurements are therefore to have a distinct place likewise in the field of anthropology. The influence of race *per se*, however, is difficult to study without the complicating factors of differences in diet, climate, altitude and general physical activity. In the comparison of the Oriental and American women these complicating factors were avoided, and the lower metabolism of the Orientals may therefore be considered to be due to a racial difference. This conclusion has led to the inception of an extensive study of the basal metabolism of the various branches of the human race.

- (7) *A respiration apparatus for a metabolic study of the various subdivisions of the human race.* Francis G. Benedict. Chinese Journ. Physiol., Report Series, No. 1, pp. 39-58 (1928).

Description of the "field respiration apparatus" (see publication No. 3 in this list) for the use of workers in China.

- (8) *Étude sur les mesures de température de la peau.* Francis G. Benedict, V. Coropatchinsky and Mary D. Finn. Journ. de Physiol. et de Pathol. gén., vol. 25, pp. 1-14 (1928).

A thermo-electric method of measuring the skin temperature is described. The thermal junctions are formed by attaching copper wire to each end of a 2-meter length of constantan wire, the free ends of the copper wires connecting either directly or by means of a switch with a portable d'Arsonval galvanometer. One of the junctions is placed in a thermostat in a constant-temperature bath and the other is applied to the skin. The thermostat consists of a well-insulated, 4-liter vessel of alcohol, in which is a 400 c.c. thermos bottle of water or alcohol, which in turn contains a small glass test tube in which is placed a mercury thermometer and one of the junctions. The alcohol in the 4-liter container is held at a constant temperature (circa 32.0° C.) by means of a bi-metallic thermo-regulator and heating coil. The application junction is in the shape of a hairpin and is protected by a special holder of hard rubber. When the hairpin junction is applied to the skin, the difference in temperature between the two junctions is indicated by a deflection of the galvanometer. The actual skin temperature is determined by placing the application junction on the skin, noting the amplitude and direction of the galvanometer deflection, multiplying this deflection by the thermic equivalent of one millimeter (obtained by calibration), and adding or subtracting the result to or from the temperature of the junction in the constant temperature bath. To aid in obtaining a series of comparable measurements on the same points of the skin, outlines of the human body (front and back) are given, on which are indicated the approximate locations of 47 points, to which arbitrary numbers have been given. The possible uses of these measurements are only briefly discussed, as the main object of the article is simply to indicate how the skin temperature can be determined in the clinic without difficulty.

- (9) *Basal metabolism: The modern measure of vital activity.* Francis G. Benedict. Scientific Monthly, vol. 27, pp. 5-27 (1928).

The material in this publication was first delivered as an address at the Carnegie Institution of Washington, Washington, D. C., on April 18, 1928. A review is given of the progress made in the study of basal metabolism since the days of the early investigators and in the development of calo-

rimeters and respiration apparatus for its measurement. This is followed by a résumé of some of the information thus far obtained concerning the factors affecting basal metabolism, such as age, weight, height, sex, food, fasting, muscular activity, mental work, sleep, undernutrition, body position, menstruation, vacation, season, exposure to cold, the neutral bath, and race. Emphasis is laid upon the fact that for every healthy individual there is a normal, remarkably fixed basal metabolism which does not undergo changes even with considerable superimposition of other factors. The special uses of basal metabolism measurements in pathology are touched upon. It is concluded that these measurements are being looked upon more and more as the best index of the vital activity of an individual, and it is predicted that in the next decade they will be included in the annual medical examination which doubtless every one will consider essential.

- (10) *The utilization of Jerusalem artichokes by a patient with diabetes.* Thorne M. Carpenter and Howard F. Root. Arch. Intern. Med., vol. 42, pp. 64-73 (1928).

The gaseous exchange, absorption of food, and composition of blood and urine were observed with a diabetic patient during a period of six days. The food eaten on four days supplied 76 grams of protein and 271 grams of nitrogen-free and fat-free substances. On five days Jerusalem artichokes provided more than 100 grams of carbohydrates, supplying about 95 per cent of the sugars. The average daily absorption was protein, 50 grams; fat, 40 grams; and carbohydrates, 205 grams—with a total energy content of about 1,500 calories. The respiratory quotient rose from a basal value of 0.84 to 0.91 as the result of the ingestion of food during the day, and the maximum increase in oxygen absorption was 14 per cent. The calculated heat production on four days varied from 1,450 to 1,550 calories per 24 hours, with 50 per cent derived from utilization of carbohydrate. Although the patient had been sugar-free on a diet in which artichokes supplied the greater proportion of the carbohydrates, when potato (containing an equivalent amount of carbohydrate) was eaten on one day, sugar appeared promptly in the urine, the blood sugar rose, and there was an increase in the heat production. The return to the use of artichokes the next day was accompanied by a disappearance of urinary sugar, a drop in blood sugar, and a lowering of the heat production. The investigation showed that Jerusalem artichokes furnish carbohydrates which can be absorbed and utilized by a diabetic patient.

DIVISION OF PLANT BIOLOGY¹

H. A. SPOEHR, CHAIRMAN

Of significance for the Division has been the consideration given to the location of a central station for work in plant biology. The study of this problem by the committee appointed by President Merriam resulted in the conclusion that of the various locations considered the Stanford University campus met most adequately the complex of requirements for such a central station. With the cordial cooperation of the authorities of Stanford University, arrangements have been effected for the leasing of land for a laboratory building site and for experimental gardens. Work on building plans and arrangement of experimental plots has also been in progress.

In several of the larger research projects now within the Division, careful study has been given to a clearer statement of the problems under investigation, to the definition of aims and the scrutinizing from different viewpoints of the methods and plans of attack. These research projects of necessity constitute investigations of long duration. They require, therefore, especially careful formulation of the program of investigation as regards definition of objectives and methods to be applied. Also, in the formulation of these programs careful consideration is being given to their correlation with the aims and results of other projects within the Division. It is the object, thus, to establish a more unified program for the entire Division, to determine what lines are the most promising and fruitful and to provide a basis for future development.

The laboratory work of the Division of Plant Biology has been conducted at the Coastal Laboratory, Carmel, California, the Desert Laboratory, Tucson, Arizona, the Alpine Laboratory, Colorado Springs, Colorado, and the University of California, Berkeley, California. Field work has also been carried on from the field stations at Santa Barbara, California, Colorado Springs, Colorado, and Mather, California.

The studies of growth and sap movement by Dr. D. T. MacDougal have been continued, with the cooperation of Professor J. B. Overton of the University of Wisconsin and Professor Gilbert M. Smith of Stanford University. Professor R. M. Holman of the University of California spent a half year at the Coastal Laboratory investigating the phenomenon of solarization in leaves. Dr. H. M. Hall is on leave of absence in Europe for the purpose of making herbarium studies of types in the groups under investigation in experimental taxonomy and transplant work. Dr. J. H. C. Smith was on leave of absence until May 1, engaged in photochemical research in the laboratory of Professor Henri in Zürich, Switzerland.

¹Work under this Division began January 1, 1928. The present report includes statements of progress concerning investigations formerly undertaken through the Laboratory for Plant Physiology and in Ecological research.

GROWTH AND SAP MOVEMENT

*The Liquid and Gas-System in Trees, by D. T. MacDougal,
J. B. Overton, and Gilbert M. Smith*

Experiments culminating the past year have shown that within the trunks of trees the water and gases are localized according to definite patterns which are quite specific for the particular species concerned. The description of the distribution of these hydrostatic-pneumatic systems (page 174) gives a picture of their physical relation to each other but nothing concerning the interactions of the two systems.

The hydrostatic system is, in effect, a series of concentric cylindrical columns extending from roots to leaves, which are laterally separated from one another by cylindrical columns of conducting elements which are gas-filled. The water-filled part of the conducting system may be under a longitudinal tension of 2-300 atmospheres and extensions or compressions of the water columns may be measured by manometers, either water- or air-filled, inserted in bore-holes in the trunk. It is impossible, however, because of many interlocking factors, to measure the degree of expansion or compression by means of manometers.

We have investigated the live oak especially to determine the inter-relationship between the two phases of the tree's hydrostatic-pneumatic system. In one tree selected for experimentation, a water-filled manometer connected with a straight vertical tube standing in mercury showed suctions of about -80 mm. Hg. A small bore was driven into this tree and connected with a vacuum chamber which could be exhausted to 750 mm. Hg. The vacuum chamber was in continuous connection with the vacuum pump, so that a partial vacuum could be maintained continuously within the chamber. Air manometers attached to this tree trunk showed that suctions were transmitted to considerable distances along the gas-system within the trunk and that these suctions could be maintained for days by operating the pump from time to time. The effect of this reduction of the gaseous pressure within the trunk is to increase the suction on the hydrostatic system and water-filled manometers register -155 to -175 instead of around -80 . In a very broad way, reduction of the internal pressure of the gaseous system is accompanied by an increase in the transpirational pull.

The effect of increase in pressure of the gaseous system upon the behavior of the hydrostatic system was also studied. Air pressures of about 4 atm. applied at a bore-hole in the trunk were almost immediately registered at nearly equivalent pressures in air manometers 2.5 to 3.5 meters above the bore. Such increase in the internal gaseous pressure within the trunk does not, however, have a corresponding effect upon manometers connected to the hydrostatic system and there is no essential change in the suctions recorded by water manometers. It is clear that varying pressures in the gas body exercise only a minor influence on the tension in the cohesive water system.

*Living Cells Two and Half Centuries Old, by D. T. MacDougal
and J. G. Brown*

A continuation of the study of long-lived cells was made chiefly for the purpose of ascertaining what progressive changes ensue in protoplasm with age and what part the environment may play in such alterations. A desert tree, *Parkinsonia microphylla*, which has been used for tests in conduction and growth has yielded results of interest in this matter.

This bean tree is a prominent member of the desert flora of the Southwest and because of its smooth green bark is known as "Palo verde." Despite the fact that its growth in thickness is at an extremely low rate, 0.2 to 0.6 mm. annually, the trunk is soft and brittle, losing 45 per cent of its dry weight in two days in the drying oven at 100° C. Bark and wood are heavily loaded with crystals, mostly calcium carbonate. The ash constitutes as much as 3.4 per cent of the dry weight.

Sections of stems 10 cm. in diameter and over 75 years old, first examined, showed occasional living ray-cells near the center and also a number of tracheids or wood-fibers in which the nucleus and cytoplasm were plainly in a normal and active condition.

An older excentric trunk which stood in a leaning position showed sound moist wood in the flank which was 9 cm. in thickness. Several counts of layers by Dr. Forrest Shreve gave a basis for the estimate that the age of the trunk might be safely taken as between 275 to 300 years. Living ray cells and tracheids could be seen in sections near the center without staining and with a dry objective. We have no hesitancy in announcing that these elements may be safely considered as having an age of over 250 years.

The tracheids composed by far the greatest part of the xylem. They measured approximately 20μ in length. Those laid down at the end of the growing season in the oldest wood near the central pith had walls averaging 4μ when measured between lumina of two tracheids, while those formed in spring and summer and measured in the same way averaged 3μ in thickness. Comparative measurements of tracheids in xylem formed in recent years was 3.2μ for those laid down in the fall and 4.2μ for those formed in spring and summer.

Living tracheids are numerous, even in the oldest part of the stem. Part of an annual ring in one bundle consisting of 120 tracheids showed nuclei and more or less cytoplasm in approximately 50 per cent of the tracheids. Likewise many of the medullary ray cells were living. Nuclei in both tracheids and ray cells were large, well-rounded and clearly showed a reticulum. One to three nucleoli were present.

The preceding paragraphs record the existence of ray cells of the thin-walled type in *Parkinsonia* and also of typical tracheids with walls in parts of trunks formed over two and half centuries ago. No observations have been made as to the length of the period of enlargement of these elements, but as the season's growth of this desert tree is completed within the brief period of the summer rains it may safely be taken to be something less than a week. Existence is continuous for 12 or 13 thousand weeks, thus

setting a new high ratio between the developmental period and the period of mature existence.

In previous contributions it had been pointed out that parenchymatous cells of *Carnegiea* which live for a century may continue to enlarge for over half this period, while similar elements in another massive cactus—*Ferocactus*—show capacity for growth during ten years of the century through which they may endure. The parenchymatous cells of the rays of the redwood (*Sequoia sempervirens*) reach full size in a few days and may live for a century, which is a very high ratio of the developmental period to the duration of life, exceeded only by that of *Parkinsonia* as noted above.

Heartwood is not always formed in *Parkinsonia*, the vessels are large and the protoplasmic strands connecting neighboring cells are well defined and numerous. By this arrangement the innermost cells are much more closely connected with the surface layers of the trunk than in the redwood or the central parts of other trunks.

The cells capable of attaining great age appear to lose their embryonic character very early. At the same time surfaces of wounds of this tree dry out so quickly that rarely is any notable callus formation found. The living cells of the trunk endure a range of temperature higher than those to which trunks of mesophytic trees are subject. The actual range, however, may be not nearly so great as those attained by cells in flattened stems in cacti in which mid-day temperatures of over 50° C. are common.

The gases in the vessels and intercellular spaces of trunks of *Parkinsonia* are extractable at about the same rate as in *Quercus*. Samples taken from bores extending 10 to 12 cm. or to the center of trunks at 0.3 to 0.4 atm. never showed less than 1 per cent carbon dioxide, and the proportions in some cases were as high as 16 per cent.

The living cells found near the center of the trunks of this desert tree are to be noted as much older than any that have been previously observed. The long-lived cells in all other plants examined were all of the large thin-walled type known as parenchyma. That wood-cells or tracheids should remain alive and retain plump and normally appearing nuclei after two and a half centuries must be set down as remarkable and without parallel in any previous observations. It may be safely predicted that larger trees may be found in which living elements of even greater age may be seen. The living cells in the trunks examined constitute a third or more of the volume of the tissues of which they form a part. The only feature yet uncovered in this preliminary stage of the inquiry that would conduce to long life in these deeply buried cells are the heavy connecting protoplasmic strands which make a dense meshwork connecting elements from the oldest to the youngest layers of the trunk.

*Relation of Living Cells to Upward Movement of Sap, by D. T. MacDougal,
J. B. Overton and G. M. Smith*

The extensive experiments carried out in California and in Arizona during the last four years furnish no support for the hypothesis of Ewart and Ursprung as to the direct action of living cells in the upward movement of sap.

The external layer of living cells encasing the perennial stem appears to form a complete enclosure for the gases accumulating in the older non-living parts of the stem. These gases may pass the living layer, which is without intercellular spaces, only by solution in the sap, and diffusion to the outer surfaces, where they may escape into the atmosphere. When sub-atmospheric pressures are set up in the non-living elements, gases in solution may be liberated from the sap.

It has been shown by our experiments that, when the atmospheric pressures in the interior of branches or stems is lowered, air appears to be drawn through the living layer into the stem, in which cases movement of gases through living cells may be taken to be notably accelerated by filtration pressures.

Living cells in both rays and xylem-parenchyma include many having a common wall with non-living elements which may be filled with solutions or with gases. The exchange of gases between such contiguous living and non-living elements would be determined by pressures, temperatures and other factors affecting solubility.

The exchange between protoplasts and non-living elements with a common wall will be determined by factors which conjoin in osmosis and which affect permeability of living membranes. Increase or decrease of hydrogen-ion pressure or acidity beyond a certain range would increase permeability so that liquids as well as electrolytes might pass freely into non-living elements in the same manner that such substances, under certain conditions, are lost to the soil. Such excretions or loss, however, would be without force or of a magnitude to affect movement of material in the conducting tracts in any notable manner.

On the other hand the radial strips of living cells form a pathway along which water may pass from cell to cell in a slow movement toward the cambium and young wood. The amount of liquid thus moved laterally would constitute the minutest fraction of the comparatively enormous amount which passes upward to the crown of a tree. The results of our experiments support the conclusions of Strasburger that sap in a stem, in which living cells have been killed by poisons, follows a path identical with that in which it ascends the trunk in a living tree, except that the indicator dyes penetrate the killed cells in the poisoned trunk. Beyond this it is established that living cells in contact with non-living units may thrust tyloses into the lumina of the conducting tracts in such enormous numbers as to materially lessen the conducting capacity of the wood. This obstructive action of living cells on the ascent of sap is an effect vastly greater than any facilitation of movement which might result from their osmotic action.

Long-lived Cells of the Redwood, by D. T. MacDougal and Gilbert M. Smith

Studies by one of us¹ having disclosed the presence of long-lived cells in certain cacti we have been led to investigate the question of longevity

¹D. T. MacDougal. *Growth and Permeability of Century-old Cells*. Amer. Nat. 60, pp. 393-415, 1926.

of cells in trunks of trees. In the coast redwood (*Sequoia sempervirens*), the first species selected for investigation, there are two different types of living cells in recently matured secondary xylem: wood parenchyma cells that stand in vertical files scattered among the tracheids and ray parenchyma cells. As in most other woody stems, the wood parenchyma and ray parenchyma cells of the alburnum or sapwood are living and densely filled with starch.

The change from alburnum to duramen (heartwood), macroscopically recognizable in *Sequoia* by a brownish-red coloration of the duramen, is accompanied by a disappearance of starch and protoplasts from all wood parenchyma cells and the formation of an orange-colored resin that completely or partially fills the lumen of the wood parenchyma. In some individuals of *Sequoia* there is a similar change in the ray parenchyma at the zone of transition from alburnum to duramen. In other individuals, however, there is only a disappearance of the greater part of the starch, and the protoplasts remain intact and show a thin layer of cytoplasm next the cell wall, a conspicuous nucleus, and a large central vacuole. Cells may remain in this condition for many years and we have observed such ray parenchyma cells 70 annual layers deep in the heartwood. Since in such trees the sapwood included 21 to 23 layers, these cells were about a century old.

Further Studies on the Path of the Transpiration Stream, by D. T. MacDougal, J. B. Overton and Gilbert M. Smith

Our determinations of the path of the transpiration stream in previous years have been made largely upon results obtained by stepping trunks of trees in dyes. These investigations have brought to light a marked zonation of the transpiration stream moving through the various annual layers, reasons for which are discussed in the next section.

Although experiments of this kind show that the transpiration stream moves through definite portions of each annual layer they do not show the relation of the stream passing through any given layer to movement within later-formed and ensheathing cylinders of xylem. A method devised the past summer has enabled us to apply dyes to certain annual rings of the tree's trunk and to exclude it from others. Thus it has been possible to determine accurately the vertical path of the transpiration stream through a given layer of the trunk and the extent of lateral (radial) movement to ensheathing annual layers of xylem as the stream moves up the trunk.

These results have been obtained by boring a hole to the center of a tree trunk and then screwing into the outer portion of the bore the tapered threaded tube devised for manometric studies in this laboratory.¹ When dye is injected into the trunk under pressure and through the tapered tube it enters the annual rings abutting on the inner portion of the bore-

¹D. T. MacDougal. *The Hydrostatic System of Trees*. Pub. 373, page 28, fig. 8C, Carnegie Inst. Wash. (1926).

hole but is excluded from the outermost annual rings which abut on the tube.

If 100 c.c. of a solution of acid fuchsin are injected into the center of a willow trunk by the method just described, it will be found that within 1 to 3 hours after the injection the dye will have traveled to the top of the tree and to many of the ultimate branches. Felling of the tree and a longitudinal splitting of the trunk shows that the dye has moved up the stem through the innermost rings but that there has been no lateral movement of the dye into the ensheathing annual rings. Thus, if dye is injected into the five oldest annual rings of a ten-year-old willow trunk the five annual rings nearest the pith will be colored by the dye but there will be no coloration of the remaining five outer annual rings.

This failure of the dye to move laterally from the inner to the outer annual rings, at least in the lower portion of the trunk, brings out quite clearly the fact that the xylem of the tree must not be regarded as a homogeneous physiological entity but, rather, must be thought of as a series of concentric cylinders which, although closely apposed to one another, function more or less independently. These experiments also show that the transpirational pull of the coherent water column in older parts of the trunk is not exerted laterally from one annual ring to the next. There is neither a pull from vessels on the inner face of one year's wood to vessels on the outer face of the previous year's wood nor a lateral pull through the medullary rays. Although there is no radial movement of dyes from the inner to the outer annual rings, one finds that the dyes eventually arrive at leaves which are in connection with xylem formed during the current year. There remains, therefore, the necessity of explaining the path by which the transpiration stream moves from the older-formed to the foliar organs inserted in the current year's wood.

The injection experiments described above show that dye starting up an annual ring more than one year old continues vertically through that ring until it reaches its distal end. If branches of the stem have annual rings in direct contact with the ring through which the dye is traveling, the dye will also move out into the branches and to the distal end of the given ring of the branch. When the dye starts up any given annual ring it may be several layers from the center of the stem. However, when it arrives at the distal end of the annual layer it is transversing the innermost ring at that part of the stem and one which is a solid instead of a hollow cylinder. On reaching the end of this innermost cylinder it then passes through the terminal portion (end) of the cylinder and into the base of the succeeding solid cylinder. Until this time the path of the dye has been through wood of a certain year's growth. The longitudinal movement from the end of the central cylinder results in its movement from wood of one season to wood formed the following season. The repetition of this longitudinal movement through successively formed cylinders of xylem eventually results in a movement of the dye to wood at the tips of stem and branches and to a region where the stem is but one year old. Here the wood is in contact with the leaves of the current year.

*Distribution of Gases in the Trunks of Trees, by D. T. MacDougal,
J. B. Overton and Gilbert M. Smith*

Studies on the nature of gases in trunks of trees by MacDougal¹ have been extended to the place where we have demonstrated the fact that the gas-body within a tree is continuous, and that pressures and suction applied to definite points in the trunk are transmitted considerable distances up or down the trunk.² An at first apparently unrelated fact was the discovery that dyes pulled through the stem by the forces of transpiration do not travel through all parts of a given annual ring, but in a definite portion only.³

During the past summer we have demonstrated by a variety of means that this zonation of the transpiration stream is due to the accumulation of gas in water-conducting elements situated in definite parts of each annual ring. The following experiments may be cited as proving this contention:

(a) If dyes are pulled through a section of a stem at partial vacuum of moderate intensity, the dyes show the same zonation pattern as when pulled through by transpiration, no matter how long the experiment is continued. On the other hand, if the suctional force of the pump is intense or long continued the dyes are pulled through all parts of each annual ring.

(b) Short sections of stems were immersed in dye in a vacuum chamber and the air exhausted. Splitting of the sections showed the dye in all parts of each annual ring. Control experiments in which sections of the same stems were immersed in dyes, but not placed in a vacuum chamber, showed only a zonal diffusion of the dyes into the wood.

(c) When a portion of a living willow stem is immersed in chloroform, ether, or alcohol, gas bubbles may be seen coming from the vessels of the spring wood but none come from the fall wood; that is, from the portion of the annual ring through which dyes ascend the stem.

(d) If dyes are injected into the stem by the method described elsewhere⁴ immediately above the bore-hole the dye penetrates all parts of the annual ring. Higher up in the stem the dye is found only in the usual zonal pattern. If the portion of the stem below the bore-hole is split open immediately after the dye is injected there will be found a zonation of the dye, but in a pattern the exact opposite of that obtained by a transpirational pull; that is, below the bore-hole the dye is only injected into such portions of each annual ring as contain gases.

In conclusion it should be pointed out that there is a seasonal variation in the extent of the gas-body, and that stems, such as the willow and the walnut, which have a well-defined gas-body in each annual ring during the summer, may have the entire annual ring water-filled at the approach of the growing season.

¹ D. T. MacDougal. *Composition of Gases in Tree-trunks*. Carnegie Inst. Wash. Year Book No. 25, pp. 160-162 (1926).

Composition of Gases in Trunks of Trees. *Ibid.* 26, pp. 162-163 (1927).

² D. T. MacDougal, J. B. Overton and Gilbert M. Smith. *The Liquid and Gas System in Trees*. *Ibid.* 27, p. 172 (1928).

³ J. B. Overton. *Stem Anatomy and Sap Conduction*. *Ibid.* 25, pp. 155-158 (1926).

⁴ D. T. MacDougal, J. B. Overton and Gilbert M. Smith. *Further Studies on the Path of the Transpiration Stream*. *Ibid.* pp. 176-177 (1928).

Such seasonal variations in the extent of the gas body account for the marked variations in the rapidity with which gas samples may be extracted from stems at different seasons of the year.

PHOTOSYNTHESIS AND CARBOHYDRATE CHEMISTRY

Yellow Leaf Pigments, by H. A. Spoehr, J. H. C. Smith and H. W. Milner

Through various improvements in extraction and purification technique, yields of pure pigments obtained have been materially increased. Thus from 100 kilos of fresh carrots there are now obtained a little over 5 grams of pure carotin; and from 1 kilo of dry spinach leaf meal, 0.45 grams of pure xanthophyll. Spinach can be obtained from the local truck gardeners during practically the entire year; about 50 kilos of the dry leaves have been extracted during this year. It has proved to be an excellent source of xanthophyll, as have also sunflower leaves, which have been grown without seasonal interruption on the laboratory grounds. From both of these sources 6 to 8 grams of crude chlorophyll per kilo of dry leaf material have also been obtained.

The question of the molecular weight of carotin, which is of primary importance for future work, has been carefully reinvestigated. On account of the complications in the solubility of these pigments and their ease of

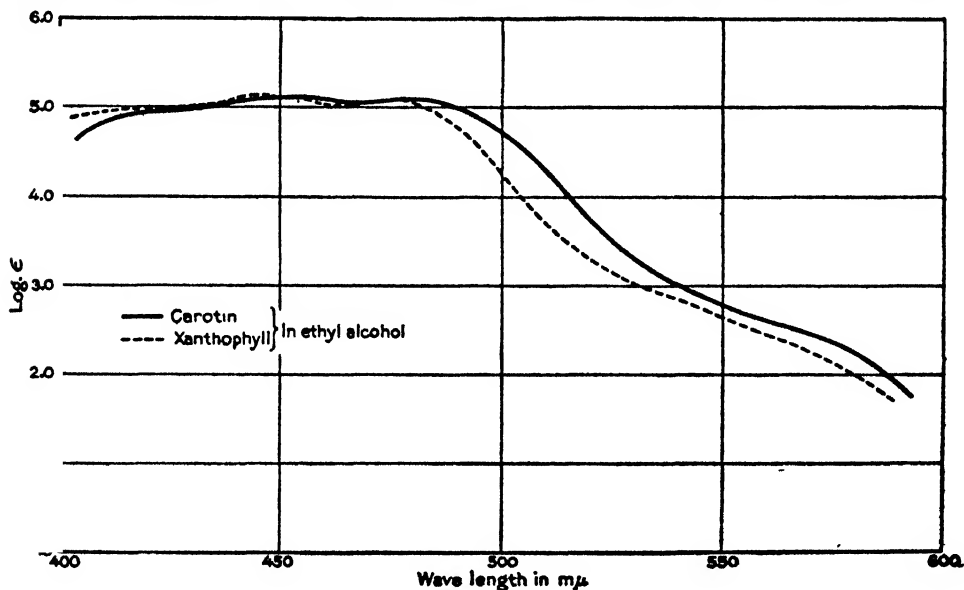


FIG. 1

oxidation and compound formation it was found that few of the methods and solvents generally used for the determination of the molecular weight of organic compounds gave reliable results. The discrepancies previously found, which indicated that the molecular weight varied with the temperature at which it is determined, are apparently due to the presence of solvents which the carotin retains after recrystallization, in spite of drying in vacuum. The low values obtained by the micro-cryoscopic method when

camphor is used as a solvent may be due to compound formation. Redetermination of the molecular weight of highly purified carotin with the Menzies-Wright ebullioscopic apparatus, using a differential thermometer and n-heptane as a solvent, gave a value of 528; by the cryoscopic method, with p-bromotoluene as a solvent, 515 was obtained. The molecular weight of xanthophyll, with the Menzies-Wright ebullioscopic method, chloroform as a solvent, gave a value of 535.

The absorption spectra (in the visible region) of carotin and of xanthophyll, both dissolved in ethyl alcohol, were determined photographically by means of a Martens polarization spectrophotometer. These are reproduced in figure 1.

Interconversion of Hexose Sugars by Means of Phosphates, by H. A. Spoehr and Harold H. Strain

Investigations on the interconversion of carbohydrates by purely chemical means have been continued, because it is becoming constantly more evident that the nature of the biologically important transformations of the carbohydrates can not be determined with certainty until the fundamental chemistry of these reactions has been elucidated. Previous work (Year Book No. 24, p. 158) had shown that the simple hexose sugars in solution with disodium hydrogen phosphate undergo mutual transformation, at room temperature, in the sense of the Lobry de Bruyn-van Ekenstein reaction. It had also been found that under these conditions one of the products formed was glucose, which was commonly regarded as being a 3-keto-hexose. Although glucose, as well as the corresponding 3-keto-hexose in the galactose series, galactose, have played an important rôle in much of the theoretical work on the conversions and dissociation of the hexose sugars, very little is known regarding these compounds. Presumably they constitute a portion of the final mixture which is formed when any of the hexose sugars are subjected to conditions conducive to mutual interconversion. By some of the workers in this field such mixtures have been considered as constituting equilibrated mixtures. But, in view of the fact that it has not been possible to obtain any evidence that glucose can be reconverted into fructose or glucose, it seems more probable that glucose represents a more stable or end product. The constitution of this compound or mixture of compounds is then indicative of the direction in which these conversions go under the influence of the reagents (catalysts) employed, and indicates whether the reaction is an intramolecular rearrangement, *e.g.* prototropy, or whether the molecule undergoes some more profound change. It has, therefore, seemed essential to determine the properties and chemical constitution of glucose, its relation to the other sugars from which it is formed and its possible rôle in the catabolism of these.

Considerable work has been done on the preparation of glucose, both by the use of lead hydroxide and of disodium hydrogen phosphate. These interconversion or "equilibrated" mixtures are characterized by a loss of the optical rotation of the solution, decrease of the reducing power and

formation of water-soluble resinous material. It is now also clear, that the product obtained by the use of stronger alkalis, such as lead hydroxide, or even disodium phosphate at higher temperatures (70°) is contaminated with a considerable quantity of organic acids. This can apparently be avoided by the use of disodium phosphate or neutral mixtures of phosphates, at lower temperatures, although a much longer time is required. The method of removing the glucose, fructose and mannose from the conversion mixture by means of fermentation with yeast is associated with difficulties and also results in contamination of the product. This in all probability is due to the formation of non-reducing gum in the fermentation process. The preparation of glutose by other workers has been subject to these two sources of contamination. For this reason there is no doubt but that the reducing power of the hexose in the glutose mixture is much higher than has been reported, namely, half that of glucose. This fact very materially affects the conclusions reached by previous workers regarding the nature of the so-called equilibrated mixtures obtained by the treatment of hexoses with dilute alkalis. Glutose prepared from glucose with lead hydroxide showed a reducing power of 51 per cent that of glucose; prepared by the same method from invert sugar the reducing power ranged from 28.6 to 54.9 per cent and prepared from invert sugar with disodium phosphate at 70° the reducing power ranged from 33 to 58 per cent that of glucose. Even greater variations in different preparations of glutose were found in the aldose content as determined by the Cajori method.

Glutose has been reported as giving a phenylosazone melting at 165° . It has been found that this osazone can be resolved into a number of compounds having a wide range of melting points. Some of these fractions analyze for a hexosephenylosazone, while others yield too little nitrogen for a hexosephenylosazone.

There is therefore little doubt that the product to which the name glutose has been given is not homogeneous but is a mixture of a number of substances which are extremely difficult to separate. There still remains the question whether this mixture contains a 3-keto-kexose. Attempts have been made to determine this by preparing the heptonic acid from the glutose mixture by means of the cyanhydrine reaction and subsequently reducing this to the corresponding heptylic acid. It is hoped thus to establish the position of the carbonyl group. A basic calcium salt of an heptonic acid has been obtained. The reduction product of this has as yet not been obtained in sufficient quantity to make possible the definite identification of the heptylic acid.

Various attempts to gain evidence of the constitution of glutose from the products obtained by oxidation with bromine and with alkaline cupric hydroxide (Fehling's solution) were fruitless because the small amounts of non-volatile acids could not be identified. This was, in all probability, due to the fact that the non-reducing gums formed by the fermentation process, were unaffected by the oxidizing reagents used and interfered with the crystallization and separation of the oxidation products.

Photochemical Action of Ultra-violet Radiation on the Vapor of Acetaldehyde, by James H. C. Smith

In recent years the application of the quantum theory to the emission and absorption spectra of gases and vapors has aided greatly in the explanation of the structure and reactivity of the molecules studied. Professor Henri,¹ in whose laboratory this work was carried out, and his collaborators, have formulated certain general laws to which these spectra conform. One of the most important of these generalizations is that three distinct regions of absorption are encountered in passing from the longer to the shorter wave-lengths. The first of these is composed of sharp absorption bands which in turn are made up of a large number of fine lines. In the second region the bands are blurred and the fine line structure has entirely disappeared. The last is a broad region of general continuous absorption. In these three regions the molecule is pictured as existing first in a quantized, second, in a predissociated, and the third in a dissociated state.

In view of these facts it is important to discover what chemical effect, illumination with light of these various regions, will have on the vapor. Theoretically light, corresponding to wave-lengths of the third absorption region alone, should produce dissociation of the molecules. Work on benzaldehyde vapor was already begun by de' Hemptinne, in Henri's laboratory, and evidence adduced in favor of this theory.

To continue the study of the relationship between absorption spectra and photochemical activity, the vapor of acetaldehyde was chosen as the subject of this investigation.

The absorption spectrum of this compound was first obtained by Schou and shown to be normal with respect to the three typical regions. It is abnormal, however, in that the bands are overlaid with a region of very slight general absorption. It became of importance then to determine the part played photochemically by this region, as well as the part played by the usual absorption regions.

Previous work² showed that two distinct photochemical reactions occur simultaneously when the vapor of acetaldehyde is illuminated with ultra-violet light; first, a decomposition into methane and carbon-monoxide; and second, a reaction which causes a decrease in pressure, probably a polymerization. To separate these two reactions and show that they are independent, required the study of the absorption spectrum, the influence of pressure, light intensity and wave-length, and the quantum yield.

The absorption curve for acetaldehyde vapor was determined by the method of Henri.³ The apparatus consisted of a 10-cm. quartz absorption tube attached to a mercury manometer and storage bulb for the acetaldehyde. Figure 2 shows the logarithm of the extinction coefficient plotted against wave-length. The bands with structure extended from 3489 to 3173 Å; the bands without structure from 3173 to 2824 Å (Schou).

¹ V. Henri and R. Wurmser, *Jour. Phys. et le Radium*, vi, 8, p. 289 (1927).

² Berthelot and Gaudechon, *Compt. rend.*, 156, 68 (1913); Bowen and Watts, *J. C. S.* 1607 (1926).

³ Weigert. *Optische Methoden der Chemie*, p. 223, Leipzig (1927).

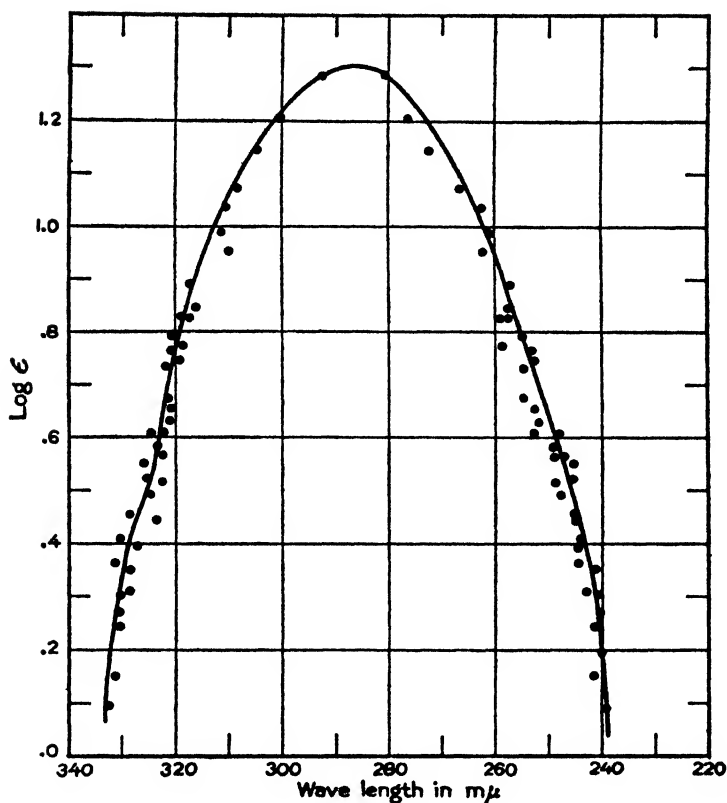


FIG. 2

The apparatus for the photochemical reaction consisted of a quartz reaction tube (10 by 1.3 cm.) fitted with two side arms, one on the bottom, ground to fit a mercury manometer system used to measure both the change in pressure due to the reaction and the actual pressure at which the reaction was proceeding; the other arm was ground to fit an outlet tube going to the

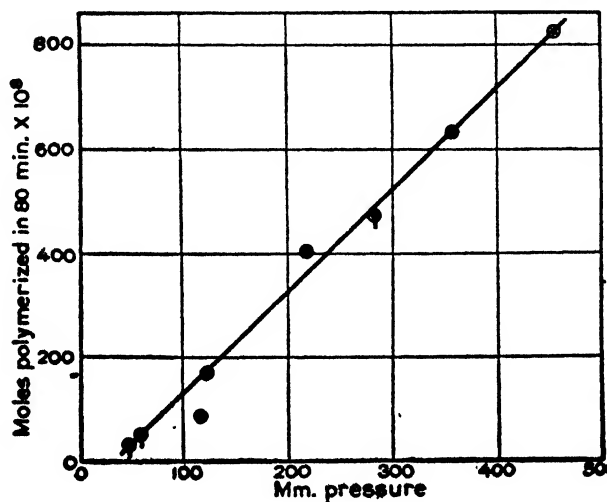


FIG. 3

gas analysis apparatus. The apparatus used for the gas analyses was that described by Christiansen.¹

The acetaldehyde used was prepared by Hollmann's method.²

INFLUENCE OF PRESSURE

By changing the pressure of the acetaldehyde vapor and using the same source of light in all the experiments of a given series, it has been shown that the number of molecules polymerized is directly proportional to the pressure (figure 3).

The number of molecules decomposed has been found to vary with the pressure, in the same quantitative manner as the amount of light absorbed. If we take the usual expression for the amount of light absorbed:

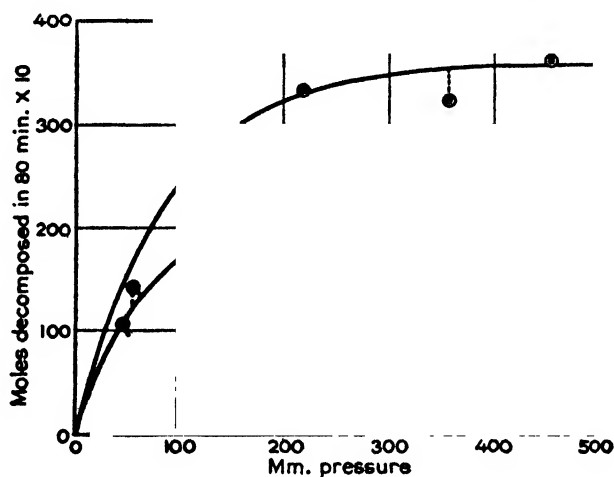


FIG. 4

$A = I_0 (1 - 10^{-\epsilon l c})$ and, assuming the gas law, transform it to pressure units,

we have: $A = I_0 (1 - 10^{-\frac{\epsilon l p}{760 RT}})$. Now, making the assumption that the number of molecules of acetaldehyde decomposed is directly proportional

to the light absorbed, we arrive at the equation: $N = k I_0 (1 - 10^{-\frac{\epsilon l p}{760 RT}}) = K (1 - 10^{-E p})$, where E is a constant and K varies with the light intensity. In figure 4 the curves are plotted for this expression, using the extinction coefficient ϵ for the wave-length 2610 Å, and K as an arbitrary constant for each set of data. Since such satisfactory agreement is obtained between the observed and calculated points, there can be little doubt that the only influence of increase of pressure is to increase absorption, and that the amount of decomposition is directly proportional to the light absorbed.

INFLUENCE OF LIGHT INTENSITY

By varying the distance of the light source from the reaction vessel, assuming the inverse square law, the influence of light intensity on the two reactions was studied. Figure 5 shows that the decomposition is directly

¹ J. A. Christiansen, J. A. C. S., 47, 109 (1925).

² Hollmann, Z. physik. Chem., 43, 131 (1903).

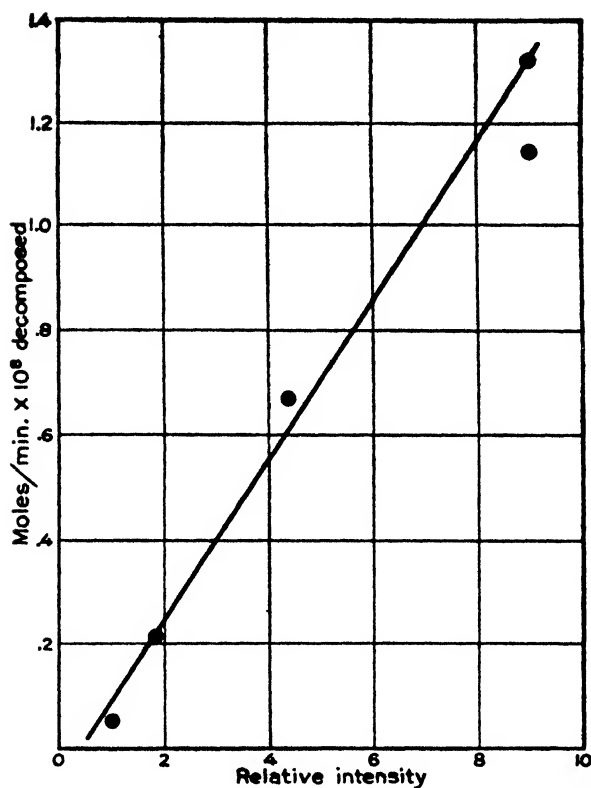


FIG. 5

proportional to the initial intensity, while figure 6 indicates that the polymerization is proportional to the logarithm of the initial intensity.

INFLUENCE OF WAVE-LENGTHS

It was of particular interest, in view of Henri's theoretical considerations to ascertain the influence of wave-length on the two independent reactions.

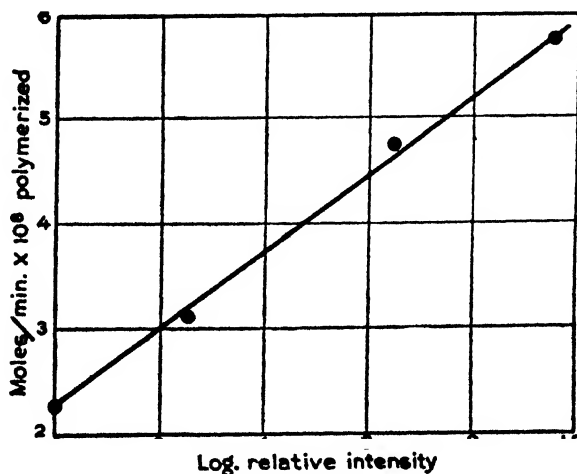


FIG. 6

For this purpose, filters isolating various regions in the absorption band were used.

It has been found that polymerization is effected by the long as well as the short waves which are absorbed, and that the amount followed closely the absorption curve. The decomposition, however, is very slow in light of wave-lengths longer than 2870 Å, even though here the absorption curve is near its maximum. Since the threshold of the dissociated state is at 2824 Å°, it is readily seen that the decomposition is produced by radiation which is in the region of dissociation only. Therefore, the theoretical considerations are entirely substantiated. It becomes evident therefore that there are two types of absorption occurring simultaneously, each producing a separate reaction. It is probable, then, that there are two chemical bonds absorbing light independently and reacting independently.

QUANTUM YIELD

The results on quantum yield were variable but all of the same order of magnitude. By using a chlorine filter and taking the average wave-length absorbed, 2650 Å, the average number of molecules decomposed per quantum absorbed was found to be 4×10^{-2} .

Solarization of Leaves, by R. M. Holman

As was first noted by Ursprung, if attached leaves of *Phaseolus multiflorus* are exposed to intense illumination until a maximum quantity of starch has accumulated, further exposure does not result in maintenance of this maximum but in a disappearance of the starch. To this disappearance of starch with continued intense illumination he gave the name solarization. He found that light in the region of the B and C lines was most effective in inducing solarization, but that visible light of shorter wave-length could cause solarization if exposures were greatly extended. The facts stated above constitute practically all that was known in regard to this effect until the beginning of the present investigation.

There is considerable evidence that in many plants growing in full sunlight photosynthesis may reach its maximum relatively early in the day and thereafter decrease rapidly in rate, while the light intensity remains undiminished. Although it seems likely that this rapid falling off in rate of carbon assimilation is due to the same causes as is the disappearance of starch, or is indeed responsible for the solarization, there have been no attempts to determine the generality of occurrence of solarization, the conditions which affect it, the real nature of the phenomenon, or its relation to photosynthesis and the daily course of starch deposition and dissolution in the green leaf under natural conditions.

These are the questions which it is proposed to study under controlled laboratory conditions in the present investigation. Since the beginning of active work on the problem in February of this year, apparatus has been developed for the study of solarization under controlled temperature, light intensity, humidity and gas supply. For the majority of the experiments *Phaseolus multiflorus* has been used; for a few, *Helianthus annuus*. As source of illumination a 1000-Watt "Spotlight" 120-Volt Mazda lamp was

employed with a plane reflector, and with a glass-walled, water-cooled cell and a shutter between the light source and the leaf. Twelve rectangular areas on the leaf surface (six on each side of the midrib) were successively illuminated, exposure in each case continuing until the end of the experiment. After removal of the chlorophyll by boiling alcohol and treatment of the leaf with dilute iodine in potassium iodide solution, the starch formation and disappearance in the variously exposed areas could be observed macroscopically.

The forty experiments thus far carried out were designed to determine the light intensity, temperature conditions, and length of exposure necessary to produce solarization, and the effect of varying the carbon dioxide concentration on the phenomenon. These experiments were preliminary in nature and the most significant ones must be several times repeated before conclusions can be stated with certainty, but the following tentative statement of facts seems to be supported by the results of these experiments:

(1) In the case of an excised, starch-free terminal leaflet of a just-matured leaf of *Phaseolus multiflorus*, the exposed area of which is not more than one-quarter of the total area, solarization takes place at about the same rate as in attached leaves.

(2) At 20° to 23° and at a calculated light intensity (from the 1000-Watt Mazda lamp) of about 60,000 lux, solarization, as judged by the reduction of intensity of the starch prints, begins after an exposure of 4 to 5 hours.

(3) Complete disappearance of starch may take place in a leaf abundantly supplied with water and showing, after exposure, no evidence of wilting whatever, so that the identification of solarization with the starch disappearance known to accompany wilting seems not to be supported by these experiments.

(4) In the case of *Phaseolus multiflorus* no solarization has been observed except in areas which show at least a slight change in color, but this color change apparently is complete several hours before there is any evidence of solarization and some time before starch accumulation reaches its maximum.

(5) Reduction of carbon dioxide concentration in the atmosphere supplied to the leaf results in more prompt solarization, a fact which may perhaps indicate that solarization is the result of a reduction in the efficiency of the chloroplasts by the direct action of light rather than through "too intense" photosynthesis.

EXPERIMENTAL TAXONOMY

Aims and Plans of the Investigations, by H. M. Hall, David D. Keck and Wm. M. Heusi

A recent survey of the investigations in experimental taxonomy has led to a restatement of their aims and of the methods employed. This, together with an outline of results obtained during the year, is presented as follows:

OBJECTIVES

Effort is made to assist in the placing of taxonomy upon a sound basis through the employment of more nearly exact methods. At present this

science is chiefly descriptive and comparative, but the tendency is toward the experimental and the statistical. It is obvious that taxonomy can not approach the physical sciences in demonstrated exactitude of its findings, but through improved methods of research and through the more rigid application of the laws of logic these findings may more and more closely approach the goal of reasonable probability.

The highest duty of taxonomy is a contribution to knowledge of the laws of heredity and evolution. Particular attention is given, therefore, to minute variations and to successive steps between these and the commonly recognized taxonomic units. It is believed that a visualization of these steps will lead not only to the true phylogenetic arrangement of plant forms, but may result in the discovery of laws of general application. Such studies call for the closest cooperation with those having the biochemic, genetic, ecologic and historic viewpoints and also for intensive laboratory and garden experiment, while a detailed field knowledge of the forms studied and their natural distribution is also essential. A synthesis from these and related fields will be necessary before a complete picture can be had of evolutionary processes.

The ability to distinguish between fixed (hereditary) characters and temporary modifications resulting directly from environmental influence is one of the first necessities of classification. Experimental methods, more direct than those of genetics, are therefore being developed for this purpose, and at the same time especial search is made for any evidence indicating a connection between modification and fixation.

A knowledge of the extent to which plants may be modified is a definite aim of the studies. Although this does not fall strictly within the scope of taxonomy, such information will serve as a check against the acceptance of extreme modifications as units in a phylogenetic classification, and, in addition, the findings may be immediately applicable to agricultural practice.

The preparation of taxonomic monographs is the most definite undertaking of the workers and the one most certain of yielding results. These monographs are for the double purpose of (a) illustrating new methods and viewpoints developed in course of the studies, especially as regards laws of variation and evolution, and (b) furnishing a classification and description of certain plant groups as contributions toward knowledge of the plant resources of the world. They are based, as far as possible, upon principles of phylogeny, since a classification following the evolutionary sequence is the ultimate aim of taxonomy.

Miscellaneous objectives include the utilization of reserve areas for scientific research and the application of botanical research to agriculture and medicine, particularly in connection with the improvement of ranges for grazing, the discovery and improvement of rubber-yielding plants for temperate regions, and the study of plants in relation to hay fever.

METHODS

COMPARATIVE MORPHOLOGY

This is the time-honored and even today the most useful tool of the taxonomist. However definite the results of other methods, they require

detailed checking through comparison between a large series of specimens. Such studies are carried out for the most part in herbaria, and the preparation of taxonomic monographs involves the critical examination of classic material, especially the type specimens, on file at the larger botanical establishments.

TRANSPLANT EXPERIMENTS

These fall into several categories, depending upon the nature of the problem to be solved. When it is desired to test the permanence of characters of related forms occupying diverse habitats, these forms are moved into a uniform environment. This is the simplest and most easily executed of all the transplant experiments. For example, if the forms appear to vary with altitude, as many of them as possible are brought together at a station of medium elevation. If the differences then disappear it is safe to assume that the original forms were nothing more than ecologic modifications. If, on the other hand, each form retains its characters for a number of years, it is assumed that the differentiating characters are hereditary. It is necessary, however, always to keep in mind the possibility that change may come about slowly through cumulative effect of environmental impact. Although this is contrary to current views of most geneticists, the possibility is so important that no time limit is set to the experiments.

Operations of a very different nature are required for inducing variation and for testing the degree to which characters may be modified by the environment. For such purposes there has been developed a type of experiment which is practically the reverse of that just described, *i.e.* instead of moving diverse types into a uniform environment a single plant is moved into diverse environments. In this process an individual is vegetatively divided and the resulting clones are planted in as many habitats as possible. Induced changes of whatever nature are of value, but chief interest lies in those which parallel the variations found in nature. Provision is now made for testing plants under five environmental complexes at one station, under three at another, and for miscellaneous plantings at several additional stations. (For details consult Year Book for 1926-27, p. 311.) It is hoped that each plant may ultimately be tested under five complexes at each of five climatically different stations, these located along a transect extending from sea-level on the Pacific to timber-line in the Sierra Nevada of California, and with one station in the semi-desert area to the east. At each station, facilities are being assembled for plantings under different degrees of light and moisture and in different types of soil.

Reciprocal transplants are sometimes made for the purpose of testing the nature of differences between related forms occupying diverse habitats. This method, developed some ten years ago in Colorado under Dr. Clements, has been in use in California for six years. It consists in moving a plant of one form to the exact spot from which the reciprocal was taken, this in turn being planted at the site vacated by the former. Thus is provided an exact interchange of environments, and the differences between the forms should vanish unless the differentiating characters are fixed. Results of high value are accumulating from use of this method, which, however, is difficult

of execution because of care needed to prevent contamination from native plants, especially through seeding, and because of hazards to which transplants are exposed when grown in unprotected areas.

The studies at present are concerned chiefly with perennial species, since complications due to heterism are thus avoided. Duplicate experiments with from five to ten individuals serve as checks against the appearance of bud mutations. The most rigid control is exercised over the operations, and "vouchers" in the form of herbarium specimens and also often of photographs are taken from time to time. It is planned also that the more interesting of the results be checked by laboratory and greenhouse experiments. There is need, further, of a detailed analysis of the environment, in order to locate, if possible, the ecologic factor responsible for the change, and, finally, of genetic and cytologic studies of resulting forms.

The transplanting of annuals involves complications due especially to the heterozygotic nature of most wild species. As a check against this it is necessary either to use pedigreed stock or to grow the plants in large numbers and use results only when all individuals under each set of conditions are uniform for the character under observation. Such experiments performed upon the *Madinæ* for several years, but discontinued for lack of facilities, will now be resumed at the new station at Stanford University.

STATISTICS

It is believed that systematic botany can be placed upon a secure basis only through the addition of statistical and experimental methods to those already in vogue. Consequently much attention is given to biometry and to a search for formulæ for expression of results. Tabulations of measurements and counts, together with percentage determinations, have been published in connection with the monographs, but for the most part they have been filed in manuscript form, awaiting the development of better methods for their utilization.

FIELD STUDIES

Since the ideal of taxonomic science is the ultimate phylogenetic classification of all natural forms of life, it logically follows that results obtained from genetic, ecologic, statistical and herbarium methods, or from any source whatsoever, must be checked against the findings of field studies. These are carried out, therefore, in as great detail as possible and have as their immediate objectives (a) the assembling of material for detailed studies, (b) the search for "intermediate" forms between recognized taxonomic units, and (c) the relation of forms to their environment and to their geographic distribution. The studies are designed, further, to explain parallel variations and to assist in the portrayal of evolutionary processes.

MISCELLANEOUS METHODS

For the realization of its ideals, taxonomy will employ many methods of investigation not here enumerated. Among the more important of these may be mentioned the cytologic, the biochemic, and the historic or paleontologic. Results from these fields will be used in connection with the present studies as rapidly as they become available.

RESULTS

The results of an intensive study of *Haplopappus*, a complex genus of the Compositæ, have been published during the year. Herbarium studies on the Madinæ, a subtribe of the Compositæ, have demonstrated that certain names commonly used in this group are erroneous and will need replacement by others of prior use; also that certain shiftings in generic and section lines will be necessary in order to bring the units into a natural classification. Publication of results as to this latter point must be withheld, however, until they can be verified by field and experimental tests.

Studies similar to those on *Haplopappus* have been initiated for the genera *Potentilla*, *Pentstemon* and *Zauschneria*, all of which enter largely into the transplant experiments. Although the investigation of *Potentilla* will be confined largely to American species, an understanding of these necessitates at least a general knowledge of the Old World forms to which they are related. Especially important is acquaintance with methods and concepts of European students of the genus. For these reasons, field and herbarium studies have been made to a limited extent in Europe, where also the cooperation of specialists has been effected.

The study of *Pentstemon* has been carried on chiefly by Mr. Keck, who has prepared a general survey of the genus from the point of view of criteria for the delimitation of sections, and in addition he has made a critical herbarium study of the section *Saccanthera*. The species of this section occur along the Pacific Coast of the United States. The majority of these forms are native to California and have now been secured for our experimental gardens. In order to secure material of those species occurring in the Northwest, Mr. Keck made a trip last fall into Oregon and Washington, where much critical material was obtained. Forty-four collections of *Pentstemon* are now under culture, representing twenty-six species or subspecies.

Some of the preliminary results obtained this year show that plants brought from 9,000-feet elevation in the Sierra Nevada Mountains to sea-level at Berkeley bloom a month before their scheduled time, retain the stature and reduced flower number of alpine dwarfs, but form broader mats. Plants brought from 5,000-feet elevation to Berkeley show increased vegetative growth, intensified flower color, and lengthened flowering period.

In connection with the taxonomic work, Mr. Keck is making studies of the hybridization in *Pentstemon*, both natural and artificial. Also, preliminary work has been done toward counting chromosome numbers in those species of *Pentstemon* in the section *Saccanthera*, to learn what help may be obtained from cytology and genetics in the classification of this group.

ECOLOGY

Investigations under the Direction of Frederic E. Clements

In previous reports the material has been organized primarily on the basis of the various projects and without especial emphasis upon the essential unity underlying them. Since the latter is regarded as the cardinal feature of ecology, the present report is devoted chiefly to the coordination and interrelations of the major projects, from the standpoint of objectives, methods and cooperation. The recognition of divisions and projects is merely a matter of convenience, intended to facilitate individual approach and to permit closer analysis, but not to conceal their basic connection. This is particularly true of the initial distinction between autecology and synecology, the one dealing with the individual, the other with the community. A fundamental and comprehensive view of the one necessarily includes the other, and the division is chiefly helpful in permitting concentration of attack or variation in emphasis. In this connection, the term autecology is also of value in stressing the broad contact between experimental ecology in field and garden, and physiology, in conjunction with the chemistry and physics upon which the latter rests.

The nature and extent of the unity involved in ecology is further exemplified by the series of climates and habitats, of vegetations and floras that constitute its research material. The climates run the entire gamut from arctic to subtropical; the series from the summit of Pikes Peak to the Great Plains comprises arctalpine, boreal-subalpine, cold-temperate and warm-temperate, and is supplemented by subtropical marine and desert climates in the region about Santa Barbara. Corresponding to these is a similar range of vegetations or climaxes, from tundra at the one extreme through forest, woodland, chaparral and grassland to desert at the other. These represent several floras distinct in origin, such as holarctic, boreal, subtropical of the Southeast, and Sonoran. Furthermore, the two mountain complexes, the Pikes Peak range and the Santa Ynez range at Santa Barbara, furnish a wide variety of edaphic habitats for the investigation of succession and adaptation.

Because of its synthetic character, ecology more than many other fields is dependent upon cooperation. Most significant and important is that with physiology and the underlying chemistry and physics, the latter being likewise indispensable in connection with instrumentation. Its problems in adaptation and competition lie in close touch with those of genetics and taxonomy, and are intimately related to similar problems in zoology. The study of vegetation from the standpoint of climax and succession furnishes the basis for the investigation of forest and range, and renders the cooperation between forestry and ecology of especial value. The great areas occupied by climaxes further makes such cooperation doubly important, since it is only by means of widely separate bases that extensive survey can be grounded upon intensive studies. The two most recent developments of ecology have been the recognition of the biotic community as the proper basis of synecology, and a growing appreciation of the interdependence of paleontology and ecology, with the consequence of a steadily increasing cooperation between them. This is most recently exemplified by the studies

of Krause (1927), who recognizes the value of succession in connection with research in prehistory.

AUTECOLOGY

FACTORS: ENVIRONMENTAL RELATIONS

This includes instrumentation and cycles, the one dealing with the intimate measurement of the habitat, the other with the climatic control, as exerted by changing cycles of various order. The first involves the utilization of standard plants or phytometers of several types as valuable adjuncts, especially in interpreting the readings obtained from instruments.

The dependence of ecological progress upon instruments was first emphasized in *Research Methods in Ecology* (1905), and a gradual advance in number and accuracy has taken place since this date. However, the requisite cooperation between physicist, instrument-maker and ecologist has been realized on an adequate scale only within the past year or two. As a consequence, it has been possible not only to improve several of the meteorological and ecological instruments, but also to adapt or develop accurate physical instruments for field use. An essential feature of this development has been a reduction in cost, in the hope of making instrumentation an indispensable part of ecological research generally. The first portable spectrophotometer, though satisfactory in most respects, left much to be desired on the score of expense, and is now being supplemented and may eventually be replaced by an adaptation of the Brace instrument. A new type of photo-electric cell with greater sensitivity in the longer wave-lengths is likewise being adapted to out-door use, and it is expected that the pyrheliometer can be applied to the measurement of radiant energy at different altitudes with little or no modification.

On the ecological side, the aerometer has been devised for securing more adequate samples of soil-air and thus permitting the determination of volume as well as composition, while a self-regulating free-water evaporimeter is being developed to furnish evaporation readings at every rain-gage installation, as well as at different levels in layered communities. Most of the simpler instruments, cog psychrometer, stop-watch photometer, etc., have been improved in construction and reduced in cost. The staff of the California Forest Experiment Station has taken the initiative in developing a new group of recording instruments, and these are now being employed in the cooperative studies of the relation of vegetation to rainfall, runoff and erosion. Others cooperating in the development of various instruments are Dr. Ellis of California Polytechnic, Dr. Boucher of Colorado College, Mr. Henson and Dr. Goldsmith.

The organization of instruments into field batteries has been based upon the principle of continuous record at minimum cost. This has led to the distinction between unit, standard and super-batteries, in accordance with the completeness of the equipment. The first represents the minimum installation for the measurement of the direct factors of the habitat, while the second comprises a complete field installation, and the last the additional instruments of record and precision proper to a base laboratory or experiment station. Major series of battery stations have been maintained for several years each in the projects in experimental vegetation and in competition, the former in a climatic series of four from Nebraska to Colo-

rado and the latter in an edaphic one of three or more at Lincoln. The number of such series in operation at present is three; of these the one at the Alpine Laboratory comprises three climatic stations from the Great Plains to the summit of Pikes Peak and three edaphic ones from sun to shade. The three at Santa Barbara are located on the south slope, crest and north slope of the Santa Ynez range, and are articulated with the forest-influence series in the several national forests.

The inclusion of standard phytometers has for several years been the regular procedure in the climatic and edaphic series at the Alpine Laboratory and is being extended to the others as rapidly as possible. In addition, sealed phytometers of native species are employed in the reciprocal gardens and transects, and in the water and shade transects, at the same time that free phytometers are utilized as controls. It is but a step from the phytometer to the indicator, and an increasing number of the latter are being used to measure seasonal and annual effects. Insert phytometers have come to have a wide range of application and are of especial value in connection with the water-cycle involved in the study of forest influences.

The investigation of climatic cycles has been approached from two directions, which, however, are intimately related. For a score of years Dr. Douglass has been studying the annual rings of yellow pine and sequoia in relation to rainfall, and the correlation of these with the sunspot cycles. This had led to the application of his methods to the relative dating of beams in the pueblo ruins of the Southwest in cooperation with Dr. Kidder, Mr. Judd and their associates, and the National Geographic Society. This work contains the promise of a dated chronology for the prehistory of the pueblo peoples, and has further value for the delimitation of climates and their changes. In close contact with Dr. Douglass's researches is the study of rainfall cycles by means of the records of all stations west of the Mississippi River. The records show that drouth periods have recurred at each of the major sunspot maxima, and the present inquiry is designed to test this coincidence for all cycles since 1830.

Both tree-growth and rainfall records are being employed to supplement the evidence of climaxes as to the natural climatic divisions, and especially with respect to the three types of precipitation, *viz.* summer, summer-winter, and winter. They serve also to check the evidences of climatic change drawn from changes in vegetation, and to supply a further basis for correlating present with past cycles. The two studies profit by the series of instrumental batteries already mentioned, as do all the major projects described below. The measurement of light and heat, of water and soil-air is prerequisite to the accurate study of the respective responses, whether functional or structural. It is equally important for the complex processes of adaptation and competition, for the understanding of climax and succession and hence for the forest and range research based upon these.

CALORIMETRY: TOTAL ENERGY RELATIONS, LIGHT AND HEAT

The importance of being able to measure the energy relations of plants by a method more accurate than that of dry weight has led to the utilization of the bomb-calorimeter for this purpose. This method has previously

been employed by Krascheninnikoff (1901) and by Puriewitsch (1913) to determine the energy used in photosynthesis. As the latter pointed out, their results agreed only in part and further applications of the method are essential to establish the facts. However, this is less important in connection with the total energy utilized by plants in growth, for which the bomb-calorimeter possesses peculiar advantages.

This project constitutes one of the best examples of cooperation between the physical sciences, physiology and ecology. It is directly connected with instrumentation through the measurement of light or radiant energy by photo-electric cell, spectrophotometer, pyrliometer and bolometer. Its application to ecological problems is both wide and fundamental, and it promises quantitative values in a field where they have been peculiarly hard to secure. In the present instance the project gains much in both methods and results from the fact that the work is carried on by Dr. Long and Mr. Haupt in close cooperation with Dr. Spoehr.

It is evident that the correlation of growth with total energy in terms of gram-calories or its multiples will yield new values in the use of phytometers and in the quantitative study of such processes as adaptation, competition and reaction. It will be possible to measure the relative absorption of energy by different species in the same uniform habitat and of the various forms of one species found in different habitats, and consequently to evaluate the rôle of various species in forest reproduction and range regeneration.

AERATION: WATER AND AIR RELATIONS

This project deals directly with the relation of plants to water and gases in the soil, and consequently is concerned likewise with atmospheric conditions. These factors, with temperature, chiefly determine the influences under which the plant obtains and utilizes radiant energy, and hence are closely connected with calorimetry. Centering about aeration are a number of long-debated questions of much importance, such as bog toxins, H-ion concentration, nitrification, bog xerophytes, etc., all of which warrant effective cooperation between the physical and biological sciences concerned.

The investigation hinges upon the reciprocal relation of air and water in the soil, and the reaction of the various types of soil organism upon these. It is based upon the method of the aerometer for securing proper samples for the determination of the volume of soil-air and of its composition by the usual methods of analysis. It also makes use of the Berlese extraction apparatus for counts of the soil fauna and employs cultures for isolating the species of algæ and fungi and ascertaining their respective rôles. The more or less antagonistic relation of water and air in the soil makes determinations of total and available water-content doubly important, since these also have to do with the question of bog xerophytes. Of a number of these investigated, *Equisetum*, *Sagittaria*, *Scirpus*, *Typha* and others have been shown to transpire like hydrophytes, while *Sabal* alone appears to have the water relations of a xerophyte. Neither the depressing effect of an oxygen deficiency nor of carbon dioxide accumulation seems to enter into the behavior of hydrophytes with aerating systems, which are typical of

swamps rather than bogs. The influence of the so-called toxins, of the pH and of inadequate nitrification upon the energy relations of true bog plants are still to be determined, and for this both laboratory and field experiments are essential.

Second only to the cooperation with Dr. Spoehr and his staff on the biochemical aspects of aeration and water-logging is that with the Bureau of Chemistry and Soils in connection with its peat investigations. It is hoped that field bases will ultimately be provided in the four important bog or swamp regions of the continent, namely, peat-bogs of the Northeast, Coastal swamps of the Southeast, tule swamps of the Pacific Coast, and arctalpine bogs of the Rocky Mountains, the Sierra-Cascade group and the Far North. Cooperating with Dr. Goldsmith and Dr. Hafenrichter in field aspects of this problem are Dr. Dachnowski of the Bureau, Dr. Wells of the North Carolina Experiment Station, and Dr. Tharp of the University of Texas.

SYNECOLOGY

The three major projects in synecology stand in close interdependence with those of the preceding section, the distinction being of importance only in so far as it serves to emphasize the community relations of individuals and species. Of necessity they rest squarely upon instrumentation and climatic studies, as they do upon the response of plants to the factors of the habitat. They are further intimately related among themselves, such community functions as adaptation, competition and reaction furnishing the explanation of succession and climax and the consequent basis for forest and range ecology.

ADAPTATION AND COMPETITION: SPECIES AND COMMUNITY RELATIONS

These two basic processes are constantly interacting in the community, cultural as well as natural, and upon them depends the outcome as to establishment and reaction. Their study rests upon the measurement of factor and function, since it is necessary not merely to know the quantity of energy and materials present in the habitat, but also the amount available in consequence of the competitive demand. Hence these two processes serve as the chief bond between the plant and community, and further exemplify the unity of ecology.

The study of adaptation in the field is greatly indebted to Bonnier (1890-1895), who was the first to develop the methods and to demonstrate the effects of reciprocal transfers from alpine to lowland. However, he was not interested in it as an ecological process, did not measure the factors involved, and hence paid but scant attention to function. The distances concerned usually limited the number of plants in each experiment to two and likewise affected the continuity of both observation and experiment. While Bonnier's general plan was followed in initiating similar studies at the Alpine Laboratory, the project was broadened to include the investigation of adaptation as an ecological process, with adequate factor measurements and control experiments (Research Methods in Ecology, 1905; Year Books, 1917-1927).

With respect to the garden installations, great care is taken to make these as natural as possible, fencing against rodents chiefly and providing a water-supply being the exceptions. The garden sequence at Pikes Peak comprises four climatic installations at 6,000, 8,000, 10,000 and 12,000 feet; and four edaphic ones, sun-dry, sun-wet, half-shade and full-shade at 8,000 feet. At Santa Barbara the series consists of marine garden at sea-level, crest at 4,000 feet and desert garden in the Santa Ynez valley. At both are series of water and shade transects, adaptation sequences of water, light or nutrients, competition cultures and reciprocal genus gardens. These exemplify the most complete expression of the adaptation method and may be illustrated by the genus *Mertensia*, which is represented by four species and a host of subspecies and minor forms in the Pikes Peak region. One garden is installed in the typical habitat of each species, and is divided into four sections. A species is planted in each section, and is represented by an equal number of individuals and of clones. The section devoted to the species typical of the habitat serves as the control, and an additional check is provided by charting and staking native individuals outside.

Phytometers of a standard plant are placed in the garden, and likewise two each of the two most similar species. The record consists of chart and photograph of each garden, of photographs, specimens, and drawings of each species, of preserved material, and of instrumental and phytometric readings. The four gardens in the case of *Mertensia* are located in the forest habitat of *M. pratensis* and the brook habitat of *M. sibirica* at 8,500 feet, of *M. lanceolata* at 10,000 feet in aspen meadow, and of *M. alpina* at 12,000 feet in alpine tundra. In addition, there are two control gardens, sun-wet and half-shade, to reveal the limit of adaptation to these factors in conjunction with water or shade transects. The other genera that contain four or more reciprocal species and have already exhibited a wide range of adaptation are *Agropyrum*, *Erigeron*, *Senecio* and *Solidago*, and these are organized into similar garden series.

In order to make the test of adaptation as comprehensive and conclusive as possible, four types of material are coming into regular use. These comprise adults selected from typical habitats, clones in the number of five or more from each parent, seedlings from open seed and from selfed flowers of the same plant. Material from the several sources is distributed as equally as possible through the gardens of a series, not only to secure controlled results from stock of fairly uniform parentage, but also to determine the course of adaptation in the four types.

The major objectives of the studies in adaptation have first of all to do with the nature of the ecological process itself, its relation to the direct factors of the habitat on the one hand and to the complementary process of competition on the other. Adaptation appears to be a necessary concomitant of mass migration under the compulsion of climatic changes, and hence promises to throw much light upon the origin and relationship of climaxes. Together with morphogeny, it is the most useful tool available for experimental phylogeny and the application of objective methods to the further development of the natural system. As an outcome of this, it is of distinct service in refining the materials with which paleo-ecology must

deal, and consequently in broadening the utilization of ecological principles and methods in the past.

Direct studies of the nature and rôle of competition have been carried out by Dr. Weaver and his assistants at Lincoln for the past four years, while the relation of this process to adaptation especially has been under investigation at both the Alpine Laboratory and Santa Barbara. The general use of the phytometer method has served to disclose the functional effects of competition and made it possible to relate the growth and behavior of competitors to physical factors in a much more definite fashion. The present need is to organize such studies on a larger scale and to work out the desired cooperation in a field where physical chemistry is so fundamental.

The investigations in the field of adaptation and competition lie on the one side in direct contact with the work of Dr. Hall in experimental taxonomy, and on the other in close touch with that of Dr. Blakeslee and of Dr. Babcock in genetics. They profit likewise by the studies of Dr. Penland upon the occurrence of hybrids in nature, especially in providing uniform material for experiment and in furnishing a test of the results obtained. They have been carried on at the Alpine Laboratory with the assistance of Mr. Whitfield and Mr. Gardner and at Santa Barbara with that of Mr. Bowman during the past three or four years. Similar methods have been applied to the study of the fungi, including the lichens, in cooperation with Dr. Shear of the Bureau of Plant Industry.

CLIMAX AND SUCCESSION: CLIMATIC AND DEVELOPMENTAL RELATIONS OF THE COMMUNITY

The biotic formation is under detailed investigation from the standpoint of factors and community functions, as well as from that of the climatic climax and its successional development. This has gained much in momentum as in detail from the bases at Pikes Peak and at Santa Barbara, not only by furnishing a complete cross-section of climates and climaxes from tundra to desert, but also from the instrumental installations available. The quantitative methods of studying communities by means of quadrat and transect have been improved and extended, and the use of the experimental enclosure developed into a standard procedure. From the large area covered by formations and their variation with season and year in response to seasonal and cyclic changes, their investigation has been largely a matter of balance between extensive survey and intensive measurement and experiment. The best solution of this problem has naturally been found in cooperation on a considerable scale, thus permitting resident investigation and detailed reconnaissance in all the climaxes concerned. A natural classification of plant communities is as much of a desideratum as one of plants or animals, and is equally fundamental to research in a wide variety of fields. The concept of development is coming to be recognized as equally valid in the one as the other, and with the concept of the complex organism furnishes a phylogenetic basis for such a classification. This emphasizes the importance of studying the climaxes of a continent in their basic climatic relations and brings into view the phyletic relationships of the vegetations of the several continents, a matter of the first importance to paleo-

botany. The inclusion of the animal life converts the community into a biotic one, subject to the same principles and methods, but comprising the total relation of organisms to each other as well as the habitat. The major clue to be followed in this maze of interrelations is derived from the fact that the plant is directly dependent upon the habitat for its energy supply, while the animal secures its energy from the plant.

The cooperative projects in this field have to do in the first instance with the climatic relations, the structure, and the development of the climax formations. Most extensive and most important of these in North America is the grassland formation, which is the object of a series of cooperative monographs. This is based upon the method of resident studies, Dr. Weaver dealing with the true prairie, Dr. Tharp with the coastal prairie of Texas, and Dr. Vestal with the bunch-grass association of the Pacific Coast. A cooperative program is likewise being carried into effect in the mapping of the vegetation of California, Arizona and New Mexico on the basis of the climax communities, in conjunction with the Forest Service, and other cooperations in the general field of climax and succession have to do with foreign vegetation, such as those of Dr. Phillips first in Cape Colony and now in Tanganyika, Dr. Borza in Roumania, etc. The developmental aspects are especially emphasized in the joint study of peat bogs and horizons with Dr. Dachnowski and Dr. Wells, and in the plans of the international committee on peat research. This is true also of the successional investigation of the extensive areas of abandoned dry-farms in the Northwest in cooperation with Mr. Carter of the Bureau of Entomology and Mr. Piemeisel of the Bureau of Plant Industry. Finally, the application of the principles and methods of ecology to the problems of paleo-botany has been carried on jointly with Dr. Chaney for several years, and has yielded new viewpoints of much value for the present, as well as for paleo-ecology.

FOREST AND RANGE ECOLOGY: EXPERIMENTAL ECOLOGY IN APPLICATION TO FOREST AND RANGE RESEARCH

The converging approaches in this field have to do with forest and range influences, the ecological life-history of the forest, the bio-ecology of forest and grassland, and succession on the range in relation to the animal population. All of these are intimately interrelated and constitute a program of interlocking projects, in which the emphasis varies in accordance with the climate and vegetation. In Southern California the conservation of water supplies rests upon the investigation of the water-use of chaparral and the course of succession after fire; at the Roosevelt Reservoir in Arizona it hinges upon the destruction of the grass cover through overgrazing and upon the consequent erosion. Instrumentation and succession are indispensable to all such studies of vegetative reactions. Installations for the study of forest influences have been made at Barranca Canyon near San Bernardino and in the Santa Ynez mountains at Santa Barbara; these consist of complete batteries of instruments, erosion areas, quadrats, transects, etc. The rate and amount of erosion is recorded by means of special types of gages, and the course and effect of the water-cycle, in terms of precipitation, interception, transpiration, etc., analyzed in detail.

The studies in forest ecology are being directed toward the problem of tolerance in the forest, the life-history and competition of dominants and subdominants, and the effect of mammals upon reproduction and succession. All of these are directly related to the development of the forest and in particular to the rôle of fire in it. The competition project has shown that both light and water are concerned in this process, and often nutrients also, and the attack upon tolerance and competition in the forest is based upon these methods and results. The new instruments and types of phytometers already mentioned, together with the calorimeter, are of the first importance in this.

The cooperative project in range research with the Forest Service and the Biological Survey has been in existence for a decade. It has dealt with the fundamental aspects of ecology in the relation of vegetation to climate and to animals, employing quadrat, transect and exclosure in a variety of sizes and forms to secure quantitative results. The principles, objectives and methods of bio-ecology have been employed consistently, and have been correspondingly extended and refined. The desire for greater uniformity in these respects and for a helpful standardization of instrument, quadrat and exclosure methods has recently led to the formation of a committee on range research, representing the several cooperating institutions.

In the forest-influence project, the Carnegie Institution is working in cooperation with the Forest Service, the program of the latter being under the charge of Mr. Kotok, Mr. Kraebel and Mr. Lowdermilk. The cooperation in the field of bio-ecological research is with Dr. Shelford of the University of Illinois and Dr. Taylor of the Biological Survey. In the various projects of the program in grazing research, the cooperators include Mr. Pearson, Mr. Cooperrider and Mr. Culley of the Forest Service, Professor McGinnies of the University of Arizona, Dr. Hanson of the Colorado Experiment Station, Dr. Tharp of the University of Texas, and the members of the research committee, Mr. Chapline, Mr. Forsling, Mr. Hill, Dr. Sampson and Dr. Taylor.

DESERT LABORATORY STUDIES

Surface Changes in a Desert Valley, by Forrest Shreve

Changes in ground level due to erosion and deposition are greater in amount and more general in occurrence in arid regions than in humid ones. The measurement of such changes was begun in 1920 in two localities, in connection with field studies of vegetation which are now in preparation for publication. The establishment of two series of permanent bench marks in the two localities has been mentioned in previous reports (1922, 1924).

The two series on the bajada of the Sierrita Mountains were planned to secure data on the behavior of the heavily loaded streamways, and a measure of the vacillation in the course of the streamways which appears to be taking place. Enough data are now in hand to show the wave-like movement of the coarse sand in the streamways, evidenced by the alternate rising and falling of level at successive bench marks. Slight lateral movements have been made by some of the streamways.

The two series of bench marks in the playa of Avra Valley are planned to show the history of a streamway of low gradient which carries a heavy load, and the history of an area subjected to periodic overflow during the last half century. During the last three years the streamway and the adjacent general surface have shown a strong tendency to upbuilding, as indicated by increases of ground level of 1 to 6 cm.

The active upbuilding of the playa area during the past three years has coincided with rainfall conditions far below the normal. Continuation of the measurements will ultimately furnish some evidence as to the comparative behavior of streams and the comparative amounts of erosion and deposition in wet and dry periods. Some evidence is in hand that the changes of vegetation which accompany upbuilding of surface are chiefly retrogressive, consisting in the slow death of well-established shrubs.

Physiological Behavior of Covillea, by Forrest Shreve

The plants which have successfully solved the problem of living under desert conditions are chiefly comprised in three groups: seasonal herbaceous plants, which pass through the dry seasons as seeds; succulent plants, which through rapid absorption and prolonged storage of water have suited themselves to conditions of torrential rainfall; and small-leaved non-succulent plants, which require a constant water supply. The first group shows little specialization, the second, represented solely by the cacti, shows great specialization and has attracted considerable investigation. The third group is more noteworthy than either of the others from the standpoint of water relations, but owing to practical experimental difficulties its members have been investigated less than their striking behavior warrants.

Work on the small-leaved non-succulent shrub *Covillea* constitutes one of the major activities at the Desert Laboratory at the present time. Attention is being focused on its relations to soil moisture, and on its conduction and transpiration, as well as on its growth and behavior in soils of different types, and particularly in soils with high content of calcium carbonate. The central point of the investigations is to determine the possible influence of soil conditions on the water behavior of the plant. Does *Covillea* live in the most unfavorable habitats of southern Arizona through elimination of its competitors by the adverse conditions, or does it possess functional features which have aided it in becoming the most widespread and abundant plant of the desert valleys?

In order to test the survival and growth of *Covillea* on soils of different types, a series of cultures was begun in the summer of 1927, in large cans containing about 0.6 cubic meter of soil. Three soils were used which are very unlike in their physical texture, on one of which *Covillea* is very uncommon in nature. With the soils of each type as a basis, cultures have been made with increasing percentages of finely divided caliche, as well as with substrata composed solely of caliche. Plants have survived in all of the cultures, but in the pure caliche and in the soils with highest caliche content the number of survivals has been smaller and the total growth has been less.

Soil Conditions in Relation to Desert Vegetation, by Forrest Shreve

Work has been continued during the past year on certain soil conditions which are peculiar to desert regions and are of importance in determining the local distribution of plants. Heavy accumulations of easily soluble and slightly soluble salts are found in many localities and are to be attributed to the prolonged existence of a climate with deficient rainfall. A study of the distribution of the heavily charged soils shows that they characterize the outwash plains, or "bajadas," of certain types of volcanic hills and mountains, and that they are absent or poorly developed in the soil of bajadas derived from granitic mountains.

The heavy accumulations of calcium carbonate and magnesium carbonate affect the physical texture of the soil, both by preventing baking and by giving favorable conditions for the formation of hard-pan, or caliche. It has previously been found in this investigation that the total soluble salts of different desert soils are not invariably in direct relation to the total salts present, and that the amount of soluble salts is not closely correlated with the type of vegetation which the soil supports. Later work has shown that the pH of granitic soils has an average value of 7.0, that of soil from volcanic bajadas an average of 8.1, while that from highly charged volcanic bajada soil gives values as high as 9.4.

The relation of caliche to the distribution of roots has been studied in a number of natural soil sections and in cuts and excavations in several types of vegetation. Roots have been found penetrating to a depth of 68 inches through soil in which layers of caliche and large concretions of the same material are strongly developed.

Experimental duplication of the conditions favoring the formation of caliche has been attempted under both greenhouse and outdoor conditions in tests which have now been running for one to four years.

The manifest importance of caliche in relation to the movements of water in the soil and its availability to plants has led to the extension of preliminary experiments on the rôle of the well-defined and extremely hard layers which are common near the surface. The water loss from caliche at the surface of the soil is much lower than from a soil surface, under the same initial conditions of water supply. Layers of caliche from 1.5 to 3 cm. in thickness are unable to transmit water from a moist layer of soil below to a surface layer above at a rate which will maintain an equality between the moisture contents of the two layers of soil. Surface layers of very hard caliche, as little as 1 cm. in thickness, are able to preserve a high moisture content in underlying soil. In spite of the slow passage of water through caliche, the discontinuous character of the uppermost layers permits the penetration of water into the lower levels of the soil during the rainy seasons. During the ensuing dry weeks the moisture thus trapped is more securely held by the soil than in localities where caliche is absent. The advantage to vegetation which caliche thus appears to possess is at least partly offset by the obstacle to root development which it presents. The dominant plant on soils with heavy deposits of caliche is *Covillea*, and it is often the only perennial present. In the course of

further work it is hoped that the ability of *Covillea* to inhabit such soils may come to be more fully understood.

Further Investigations into the Causes of Variations in the Transpiration Rates of Desert Perennials, by Edith B. Shreve

Previous work¹ has shown that *Encelia farinosa*, a highly successful desert perennial, has some means of retarding its rate of water loss to the air during the hot dry months. Stomatal movements and changes of leaf structure were shown to be only partly responsible for this retardation. Changes in the chemical constitution and in the osmotic concentration of the sap as well as in the total imbibitional capacity occurred in such a way as to make it highly probable that they also were responsible for the retardation.

Consequently an investigation has been planned, the object of which is to search for the underlying physical principles which may cause retardation of transpiration when the external conditions demand positive acceleration.

In plants, the water which replaces that lost by transpiration must, at one place or another, pass through or come from cells that are enclosed by semipermeable membranes. The solutions within these cells have an attraction for water due to their osmotic or imbibitional forces, and hence on theoretical grounds would retard the rate of replacement of water to the transpiring surfaces in varying amounts. In order to reduce these phenomena to their simplest form an apparatus has been designed and built in which the force of osmosis is allowed to act against the forces causing replacement of water to a membrane from which water is evaporating.

The apparatus consists of a glass osmometer connected by glass tubing to a glass evaporimeter. Between the two is a manometer containing a mercury bubble. Both osmometer and evaporimeter are constructed so that any desired kind of membrane may be used. The apparatus is made entirely of pyrex glass and metal and is strong enough to stand the strain caused by several atmospheres of pressure. The rates of evaporation or of osmosis can be measured separately. By a proper manipulation of stopcocks, the rate of evaporation can be read when the force of osmosis is working against the evaporation.

An air chamber has been constructed to hold the apparatus, which maintains a temperature constant to 0.05° C. between the temperatures of 10° and 40° C.

The influence of temperature and concentration on the rate of osmosis is being measured as a necessary part of the investigation. Potassium ferrocyanide membranes and cane-sugar solutions from molecular to 0.01 molecular concentrations have been used to test the purely physical behavior of the apparatus. Many readings have been taken but the results are not yet worked into final form. Enough has been done to show that the study of the problem by this method has many possibilities, both from the standpoint of pure physical chemistry and from that of plant activity.

¹ Edith B. Shreve, *Ecology*, IV, 3 (1923); *Bot. Gaz.* 77, 432-439 (1924).

Analysis of Gradient Functions, by R. M. Fraps

The investigations in progress are directed toward the quantitative analysis of the organismic relations embodied in the gradient theory of C. M. Child, with special reference to energy exchanges. Preliminary problems of fundamental importance have arisen out of theoretical and methodological considerations. These have been treated independently under the divisions noted below. *Planaria dorotocephala* or *Planaria agilis* have been used as experimental material.

RELATION OF OXIDATIVE RATE TO PRIMARY ENVIRONMENTAL FACTORS

The first object herein is to define accurately all experimental conditions. Following are the values of the several environmental factors adopted as standard: (1) Temperature, 23°; (2) Oxygen tension, atmospheric; (3) Chemical constitution of Medium: (a) For whole worms simplified solution: $\text{NaHCO}_3 = -0.0084$ per cent, $\text{KCl} = 0.0002$ per cent, $\text{CaCl}_2 = 0.0042$ per cent; (b) For sections: $\text{NaHCO}_3 = 0.0084$ per cent, $\text{KCl} = 0.002$ per cent, $\text{CaCl}_2 = 0.042$, $\text{NaCl} = 0.022$ per cent; (4) CO_2 tension, zero.

All other basic environmental conditions are fixed by the above constants.

The second object is to determine the dependence of the rate of oxygen consumption on change in value of a single environmental factor. The simplest possible condition for the change of oxidative velocity in comparable tissues is thereby given. Results in this connection have been obtained for the relation of rate of oxygen consumption to oxygen tension, carbon dioxide tension at constant pH, change in total salt concentration, change in Ca concentration, change in bicarbonate concentration at constant pH, and change in pH through variation of CO_2 tension and bicarbonate concentration.

ACTION OF IODINE AND THYROID PREPARATIONS ON THE RATE OF OXYGEN CONSUMPTION OF PLANARIA

Iodine decreases the rate of oxygen consumption in comparatively low concentrations. For a concentration of 0.000035M the decrease in oxygen consumption of large *Planaria* is close to 40 per cent. Concentrations greater than this produce typical susceptibility gradients. Very low concentrations apparently lead to slight increase in rate of oxygen consumption (ca. 10 per cent); this effect probably is due to increased motor activity.

The results with thyroxin tablets, Squibb, in aqueous solution, show the typical delayed thyroid effect on oxygen consumption of *Planaria*. The initial effect of the substance is a decrease in the rate of oxygen consumption. This action is probably due to the relatively great amount of organic matter with which the thyroxin is combined.

MEASUREMENT OF GRADIENT DIFFERENCES IN SECTIONS OF PLANARIA

The first experiments toward the actual analysis of gradient differences have been completed. These have for their end only the measurement of the actual difference in rate of oxygen consumption in isolated sections of *Planaria*. The rate of oxygen consumption of anterior and posterior sections of the anterior zooid of 14-mm. *Planaria*, from the twelfth to the

fifteenth hour after section, shows a decrement of 15.5 per cent to 21.2 per cent in the posterior section.

METHODS: REFINEMENTS IN MANOMETRIC DETERMINATIONS OF GAS EXCHANGE

A new "Universal" type of chamber has been perfected. Any number of such chambers may be used on a given manometer; it is thereby possible to carry out several experimental series simultaneously, over long periods of time without transference of material into and out of a single set of chambers for each determination of oxygen consumption. With the improved apparatus, the determination of oxygen consumption is possible to within ± 0.05 cu. mm.

Meteorological Investigations by Means of the Long-period, or Seasonal, Rain-gages, by Godfrey Sykes

The winter season of 1927-28 was marked by extremely light and infrequent precipitation throughout the region under observation. The records at the Desert Laboratory show that, during the nine-month period from the end of September 1927 until the end of June 1928, the precipitation (2.64 in.) has taken place in measurable quantities upon eighteen days, and that upon only seven of these days has it exceeded 0.10 of an inch.

Similar conditions have been found to exist along the line of observation stations paralleling the Mexican border to the southwest of Tucson, at which long-period rain-gages have been installed.

The line of stations extending through northern Sonora to the shore of the Gulf of California registered light and uniform precipitation, with indication at one station (Kino Point) of a rain storm of torrential force and volume.

It is becoming increasingly apparent that rainfall data require careful interpretation in relation to vegetation in a semi-arid region.

Delta of the Colorado: Observation and Investigation of Recent Changes, by Godfrey Sykes

The work of investigating and recording the rapid and important changes which are taking place in the delta of the Colorado River has been continued. Great topographical changes have been brought about in the delta during the last twenty-five years through the combined action of occasional great floods, engineering works of a tentative nature, the heavy deposition of silt and the rapid growth of dense vegetation.

The river was unusually low at the head of the delta during most of the winter months. The volume of discharge at the intake of the Imperial Canal was for some time less than the requirements of the Imperial Valley, so that the whole flow was diverted into the canal for several weeks, leaving the new delta-cone quite dry. This condition was favorable for the continued growth of the dense screen of vegetation which covers most of the region, so that it is doubtful whether a definite channel will yet be opened to the estuary.

The silt-volume of the June flood was unusually high, and it is therefore likely that deposition will be found to have been very heavy during the

period of submergence. The partially clarified water finds its way into the Hardy, but the main body of the silt remains entrapped amongst the vegetation.

Under the conditions of soil and vegetation which obtain over the central and southern parts of the delta, the stabilizing gradient seems to be at about 1.5 feet per mile, so that a surface slope of this grade is now being formed over the area of deposition and the nose of the fan is being steadily thrust toward the Gulf. If this condition can be maintained it is obvious that a protective barrier will be formed which will eventually make easier the task of re-diverting the river into the meander strip which it occupied for fully seventy years during the last century.

DEPARTMENT OF TERRESTRIAL MAGNETISM ¹

LOUIS A. BAUER, DIRECTOR

JOHN A. FLEMING, ASSISTANT DIRECTOR

GENERAL SUMMARY

The preparations for and the initiation of the seventh cruise of the *Carnegie* have made large demands upon the energy, initiative and interest of the entire personnel. The vessel left Washington on this three-year cruise May 1, 1928, as planned. At the end of the year covered in this report (July 1, 1927, to June 30, 1928) excellent progress under the capable leadership of Ault had been made, which, despite the ambitious program undertaken in magnetic, electric, oceanographic and meteorological observations, gives good promise of worth-while results in all these fields. An inspiring feature of the preparations has been the generous cooperation extended by interested investigators and organizations everywhere.

The demands of the *Carnegie*, however, have not prohibited good progress in our other activities. The developments in the investigatory work have continued along lines as planned in previous reports in the compilation and study of accumulated data on the correlation between solar and terrestrial phenomena, on the laws governing diurnal, annual and secular changes and space-distribution in terrestrial magnetism and electricity, on the definition of truly representative measures of magnetic and electric activity really interpretable from the laboratory point of view to permit analyses of the irregular phenomena and disturbances.

The problem of finding a suitable correction to be applied to the results of field-observations for each of the three magnetic elements, in order to eliminate the effects of hour-to-hour and day-to-day inequalities, has been given considerable attention by Fisk. Observations in the field for diurnal variation, which have been regularly made for several years, have been found very useful. The feasibility of using the variations recorded at an observatory at a distance from the field-station, in the solution of this problem, was examined by comparing those records with variations actually determined in the field, and by comparing records at different observatories for the same day with each other. The collection and preparation for use of the magnetic data available for a general review of the rates of secular variation of each of the magnetic elements at the present time has also received attention.

Pickard's investigations of correlations of terrestrial magnetism and electricity and of solar activity with radio-reception conditions are of increasing significance. In this field the improvements made by Breit and Tuve in the procedure for measuring effective heights of the Kennelly-Heaviside layer are important. The transmission consists now of very short pulses separated by relatively long intervals. The duration of each pulse is of the order of one six-thousandth second, successive pulses being separated by

¹ Address: Thirty-Sixth Street and Broad Branch Road, Washington, D. C.

about one two-hundredth second, with occasionally longer intervals. Interference between the ground-wave and its reflection is now completely eliminated and quite unambiguous results as to height have been obtained.

The high-voltage work begun last year was continued. With the means available a voltage of 5,200,000 volts was obtained. The ultimate limitation with the method used was due to the breakdown of insulation between turns of the Tesla coil. Higher potentials can doubtless be reached as soon as this is necessary by a proper modification in the coil-construction. Meanwhile the means already developed have been used for work with vacuum-tubes. A potential of 1,000,000 volts has been applied to a vacuum-tube. The ultimate purpose of the work being the production of high-speed electrical particles, a method of accelerating electrons to a speed corresponding to about 1,500,000 or perhaps 2,000,000 volts has been developed.

Additional experimental results obtained during the past year, in cooperation with the Bureau of Standards, are in perfect accord with the earlier results obtained at the Department's laboratory on the permeability of iron in high-frequency magnetic fields.

Practically uninterrupted records of the magnetic elements and of the atmospheric potential-gradient and positive and negative conductivity were obtained throughout the year at the Watheroo and Huancayo magnetic observatories and of potential gradient and negative conductivity at the observatory on the deck of the laboratory at Washington.

Records of earth-currents were obtained at Watheroo and Huancayo, with only slight interruptions during the year. A new electrode-system was installed at Watheroo with a view to eliminating certain disturbing factors. The precision now obtained appears to be such that with a few years' additional records, detailed quantitative comparisons with associated phenomena will be justified.

Increasing interest in the methods developed in the Department for earth-resistivity surveys has been manifested, especially with a view to its use in the location of minerals hidden in the Earth's crust. Surveys were made in the Michigan copper country during the summer of 1927, in cooperation with the Michigan College of Mining and Technology, to obtain further checks of the interpretation and to extend our knowledge of the resistivity of Earth materials.

Improvements in instrument design particularly for atmospheric-electric observations have been made as the result of laboratory experiments. These improvements make possible more rapid observation and more accurate results, particularly in the apparatus for measuring conductivity, ionic content and penetrating radiation.

The activity of various governments and organizations in our fields has continued the marked increase reported last year. We have used every opportunity through instruction and loan of apparatus to encourage this and have effected additional cooperative arrangements both for magnetic and electric work. It is hoped that these may be increased in such number as to insure the continuity of secular-variation material and to offset the necessary curtailment in our field-operations to concentrate upon theoretical discussions and laboratory attack.

INVESTIGATIONAL AND EXPERIMENTAL WORK

TERRESTRIAL MAGNETISM AND ELECTRICITY AND COSMICAL RELATIONS

The theoretical investigations during the year in large measure have been in continuation of those noted in last year's report (pp. 167-168).

Studies of correlations between solar activity and the Earth's magnetic and electric fields—Increased emphasis is being given the important and vital question of satisfactory measures for magnetic and electric activity; these must be such that account is taken of space-distribution of the stations for which activities are to be determined. Correlations of terrestrial magnetism and electricity with radio reception and solar conditions have been further studied. These discussions have been carried on by Bauer, Peters, Duvall and Ennis. In the preparation of matter concerned with the propagation and methods of analysis of magnetic storms for consideration at the Prague Assembly of the International Geodetic and Geophysical Union, Bauer and Peters prepared memoranda on and illustrations of typical disturbances. The helpful, cordial cooperation with interested organizations and individuals mentioned in last year's report has been maintained.

Reduction of accumulated magnetic data to common epoch—In the development of analysis of the Earth's magnetic field an important step has been in the reducing of magnetic results to a common epoch. These reductions to the epoch 1913.5 for the region immediately northeast of Australia have been completed by Bauer, Peters and Duvall. Fisk has continued his study of secular variation and is now engaged in discussing such data for Africa (see p. 222).

Investigations of ship-deviations caused by rolling of the ship—Experiments were made by Peters and Green with an especially designed compass, with a view to differentiate between the deviations caused by ship's motion by tilting and those caused by the non-coincidence of the center of mass and the point of suspension. The mathematical problem of tilting deviations was studied by Peters and Duvall and applied to the experimental results. A preliminary value of the deviation was calculated from the numerical solution of the differential equation of motion according to F. R. Moulton as obtained for the damped motion of a magnet in a uniform field of varying intensity.

Investigations of the feasibility of gyrostat control at sea—These investigations were made by Peters and Soule for the purpose of determining the practicability of reducing the motion of gimbal-mounted instruments at sea, with a view to securing greater precision in the results and reducing the time of observations.

Magnetic charts for polar regions—The indexing of available data and their reduction have been continued by Peters. These were also utilized in preparing memoranda and instructions for cooperative field-operations in these regions between the Department and special expeditions and organizations developing plans for exploratory work.

CONTRIBUTIONS OF RESEARCH ASSOCIATES

Dr. A. E. Kennelly has continued his associateship during the year. He visited the laboratory in Washington, June 17, 1928, and discussed certain features of the conducting-layer and high-potential investigations and of the atmospheric-electric and earth-current programs and inspected some of the records from the two observatories. He has suggested several lines of investigation based on the records.

Since the last annual report, Dr. S. J. M. Allen and his assistant D. W. Dwight, of the University of Cincinnati, have made progress in the construction of apparatus (see p. 168 of annual report for 1926-27) for the measurement of the differential charge (plus or minus) of the atmosphere in different localities. Changes in design and modification of the experimental procedure have contributed to delays which, at present, prohibit the reporting of actual data, but the few remaining difficulties, it is hoped, will be soon overcome. Most of the work for the past year has been to devise the apparatus to be self-recording, clockwork closing a magnetic switch which closes the circuit for the pump-motor, starts the rotation of the drum which carries the sensitized paper, and also breaks the ground-connection of the recording electrometer. By means of a second electrometer, similarly controlled, a record of the atmospheric potential-gradient is to be made on the same paper, readings to be taken every half-hour. The pump is driven by an 18-volt shunt-wound motor, and the entire apparatus, aside from the "B" batteries used for charging the electrometer-needle, can thus be operated in the field by three 6-volt storage-batteries.

Greenleaf W. Pickard continued as research associate and has made several valuable contributions besides securing cooperative effort and observations in several directions. During the year ending June 30, 1928, the measurements of night broadcast-reception in Newton Center, Massachusetts, from station WBBM of Chicago, begun by Pickard in February 1926, have been continued, and there is now available a substantially homogeneous body of nightly field-values extending over an interval of two and one-half years. Since July 19, 1927, these have been valuably supplemented by a cooperative observer, Howell C. Brown, who has made nightly measurements at Pasadena, California, of the field from a broadcasting station in San Francisco. In February 1928, the nightly recording and measurement of the Chicago station was transferred from the laboratory at Newton Center to the Harvard Astronomical Laboratory at Cambridge, Massachusetts, where it is now being carried on under the direction of Dr. Harlan T. Stetson. This transfer has given more time for correlation of reception-data with terrestrial and solar elements, and also for special measurements, including the continuous recording of several low-frequency stations on the Atlantic coast, which is now being conducted in cooperation with Austin and the Bureau of Standards Laboratory for Special Radio Transmission Research.

A special study has been made during the past year of the relation between night-reception, sunspot-position and sunspot-area (see p. 261). More recently, finding that reception was in general more disturbed by the transit of single spots than by sunspot-groups, an investigation was begun of the

relation between night-reception and regular bipolar groups. Although this study is far from complete, and will require at least two years' additional reception-data before the relation can be definitely evaluated, it appears that the reception-depression associated with the transit of the group depends upon the angular separation between the two spots; the greater this separation the more marked the reception-disturbance becomes. It seems possible that this relation is a result of the magnetic field of the sunspot-group acting as a director for the alpha-particles or beta-particles emitted from the vicinity of the spots. When the spots are close together the external magnetic field would be strongly curved and would therefore tend to bend back sunward all corpuscular radiation; when the spots are widely separated, their fields and hence the beam of projected particles would be more nearly radial, so that more would reach the Earth.

Another recently found relation is between night-reception, air-temperature, and pressure at or near the receiving point (see p. 261). Reception and temperature at both Newton Center and Pasadena are found directly related, maximum reception being associated with maximum temperatures and vice versa. This is the reverse of the relation previously found by Austin for day-reception, where falling temperature improved reception, and is therefore another case of the already established inverse relation of day- and night-reception. A correlation between night-reception and pressure was also found, signal-strength increasing as areas of low pressure passed over the receiver and decreasing with the passages of high pressures. The Pasadena observations have been of great value in this work, not only as a check upon relations found for the Chicago to Newton Center transmission, but because (perhaps for the reason that the San Francisco to Pasadena path has a considerable component parallel to the Earth's magnetic field, while the Chicago to Newton Center path is nearly magnetically west to east) the Pasadena night-fields have relatively small correlation with either solar activity or terrestrial magnetism.

Dr. H. U. Sverdrup of the Section of Meteorology of the Geophysical Institute of Bergen, Norway, was appointed as research associate beginning April 1, 1928. He has acted in an advisory capacity as regards the magnetic and atmospheric-electric program of the Department generally, but his activity has been more intensively concerned with the preparations for the program in physical oceanography on board the *Carnegie* for Cruise VII. Not only has this been advantageous because of his own wide experience in this field but also in establishing connection between the Department and institutions, the assistance, interest and cooperation of which have been found invaluable. In particular he has advised as to selection of some of the instrumental equipment and has supervised the construction or tests of instruments ordered in Norway and Denmark. He met the *Carnegie* at Hamburg on her arrival there June 22 to put Captain Ault and his staff in touch with the German men of science who were interested in the work of the *Carnegie*. He also discussed a number of practical details with Captain Ault and members of staff.

In May Dr. Sverdrup represented the Carnegie Institution of Washington at the centennial celebration of "Gesellschaft für Erdkunde zu Berlin" and

presented an abstract of a paper by Fleming and Ault detailing the plans for the scientific work of the *Carnegie* on Cruise VII.

MAGNETISM AND ATOMIC PHYSICS

ATOMIC PHYSICS

The investigations in the fields of atomic physics were continued by Breit, Tuve and Dahl, with assistance in instrumental design and electrical installations from Huff, and may be summarized as follows:

Source of high potential—The ultimate limitations of the Tesla coil of the type used (see p. 169 of last annual report) have been investigated. It has been found that a Tesla coil used in good transformer-oil with a pressure on the oil of 500 pounds per square inch can give a potential of 5,200,000 volts between its terminals. The pressure on the oil improves its dielectric strength sufficiently to practically eliminate the danger of corona-discharges at the spherical 8-inch or 10-inch caps protecting the ends of the coil. The film of oil between successive turns apparently is also improved by the pressure. But this pressure is insufficient to avoid breakdown if the voltage is too high. Thus coils of the present construction, wound on a 3-inch Pyrex glass tube having a length of one meter and wound with No. 38 or No. 40 wire, have an insufficient amount of insulation between turns to perform reliably above 5,000,000 volts. The difficulty can doubtless be eliminated by using somewhat more elaborately constructed coils. Since no urgent need for voltages higher than five million has been felt, most of the efforts have been devoted to the study of the application of the easily obtainable voltages to vacuum-tubes.

The ultimate aim has been of course that of artificially obtaining particles comparable in speed and energy to the beta-particles and alpha-particles ejected by radioactive materials. Two ways of doing this have been tried: (1) That of accelerating electrons, or protons, or ionized atoms by means of a high potential; (2) subjecting a particle to an accelerating field due to other actions than those of a high potential. Beginnings have been made in investigating these possibilities as indicated in the following sketches of progress.

(1) The direct application of high potentials to vacuum-tubes is connected with some difficulties. It is well known that the construction of a 100,000-volt X-ray tube is very easy while a tube operating at 250,000 volts is relatively hard to make. The exact reason for this is not known and the subject is on the whole in a very empirical state. It has been suspected by other workers that the main difficulty lies in the metal electrodes which are usually introduced into the evacuated X-ray bulb. For this reason an attempt has been made to apply accelerating fields to a vacuum without the use of internal electrodes. This is possible with the rapidly alternating voltages obtainable by means of Tesla coils. It is usually difficult and practically impossible with the steady or slowly alternating potentials commonly used. By using external electrodes, 1,000,000 volts have been applied to a 9-inch bulb immersed in oil which was kept on the pumps during operation. This method has its limitations. Only a limited amount of current can be passed through the tube if external electrodes are

used. For the purposes in view, however, it may give a sufficiently powerful source. So far it has not been found possible to run such tubes reliably. Some unknown factor has not been traced. Punctures frequently occur.

(2) The production of high-speed electrons without the use of high voltages has been attempted and apparently accomplished. The underlying idea of the method is to make use of the well-known law of induction discovered by Faraday—the same law on which the operation of a dynamo is based. If a coil is put in a magnetic field a current is induced in the coil whenever the magnetic field is changed. The current is due to the electric field caused by the changing magnetic field. A change in the magnetic field always gives an electric field. The more rapid the change the higher is the electric field. The equipment constructed in the laboratory of the Department makes it possible to obtain very high rates of change of magnetic field through a relatively large area. Thus a field of 30,000 gauss can be built up through 20 square centimeters in one one-hundred-thousandth of a second or even more rapidly. Since electrons accelerated even by relatively small voltages travel very fast it is possible to arrange an apparatus in which the electrons are made to encircle several thousand times the evacuated region in which the high field of 30,000 gauss is being built up in the short time of one-hundred-thousandth second. Every time the electron encircles the area its speed is increased by an amount roughly corresponding to 500 volts as may be verified by calculation. Now several thousand revolutions of an electron, each of which gives an acceleration of 500 volts obviously gives a resultant acceleration equivalent to several million volts. A calculation intended to be accurate for the apparatus actually constructed indicates that the equivalent voltage is in the neighborhood of one and one-half or two million volts. Almost no trouble has been experienced in operating the apparatus. The same tube has been kept on the pumps continuously for about three weeks, being used for various tests almost every day. The low-voltage (50,000-volt) electrons enter a 3-inch bulb near its wall, spiral in toward the center, and hit a target at a distance of about 3 mm. from the center. No provision has been made so far to repeat the process very often. The ordinary runs consist in producing a parcel of high-speed electrons only once every second, the parcel including only the electrons drawn from the filament in one-millionth second. The radiations obtainable so far, therefore, are very weak and intermittent.

Quantum-mechanics—Two minor contributions to quantum-mechanics have been made: (1) An exact solution for the behavior of electrons reflected by a uniform retarding field of force has been worked out. The transition from the classical to the quantum-condition has been studied. The calculation shows that the phase of the wave representing reflected electrons deviates from that expected on the classical theory by very appreciable amounts. In particular a critical point in the variation of phase occurs if $4\pi m^3/(3\lambda a) = 0.1$, where m is the cosine of the angle of incidence, λ is the wave-length of the incident electrons, a is the reciprocal of the distance in which the refractive index of the reflecting region of force changes from 1 to 0. These calculations also make it possible to discuss accurately some types of reflections of radio waves. (2) A study of Dirac's new theory of

the electron showed that a possible interpretation of it lies in the impossibility of measuring with certainty any velocities different from the velocity of light. (For abstracts of these contributions see p. 240.)

HIGH-FREQUENCY PERMEABILITY OF IRON

Wait with Brickwedde and Hall of the United States Bureau of Standards continued the cooperative investigation by the Bureau and the Department (see p. 171 of last year's report). In view of newly published results by Mitiaev they made an investigation (see p. 267) on the resistance of iron wire to a high-frequency current, using wires intermediate in size between those used by Mitiaev. The method followed in measuring resistances in the present investigation was such as to give more accurate determinations than did the method employed by Mitiaev. The wave-length region between 70 and 120 meters was covered in the present investigation without finding a critical variation in resistance, consequently there can be no critical variation in permeability for these wires in that region. The results are consequently in agreement with those previously found by Wait and by Wait and Brickwedde (see p. 170 of last annual report).

KENNELLY-HEAVISIDE LAYER MEASUREMENTS

Measurements have been continued by Breit, Tuve and Dahl of the effective heights of the radio reflecting-layer during various periods through the year when transmission was available. The echo-method was used, as developed here in the summer of 1925. Some preliminary observations were also made by Appleton's method (see Proc. R. Soc. A., vol. 117 (1928), p. 576, and earlier papers) but more complete observations by this method were postponed until a later date. In the echo-method a transmitter is arranged to send out a series of very short "dots" or "peaks" whose duration is one-thousandth of a second or less, separated by intervals of about one-hundredth of a second, and an oscillographic record is made of the received signals. At times only a single set of "peaks" is observed at the receiver, corresponding to the direct wave over the ground from the transmitter, but when the reflecting layer is active one or more sets of reflected peaks follow those due to the ground-wave. The height of the reflecting layer or layers is then directly measured by the delay in the time of arrival of the reflected peaks after the ground peaks. The signals were transmitted by the U. S. Naval Research Laboratory at Bellevue, Anacostia, D. C., about 7 miles from the receiver at the Department, and, as before, the transmitter which was available was one which operated at a frequency of about 4,000 kilocycles. All observations were made during daylight hours.

An important improvement was made during the fall of 1927 in the type of signal sent out by the transmitter. Hitherto the 20-kilowatt crystal-controlled transmitter was modulated by the positive half-waves of a 500-cycle electromotive force and rapidly keyed (on and off) in addition. The transmission consisted of groups of peaks, each peak of duration about one fifteen-hundredth of a second, and separated from the next peak by an interval about twice as long. With this arrangement the reflected peaks were almost never completely resolved from those due to the ground-wave,

and the keying was further necessary to eliminate the ambiguity in their identification. Due to the overlapping of peaks there was the possibility in many cases of misleading results due to the interference of waves arriving at the receiver over different paths. A modulating device was designed and applied to the transmitter which gives an almost ideal signal for the echo-method. It is based on the sudden pulses of plate-current which occur in an unbalanced multivibrator-circuit, and gives a signal comprised of peaks of a duration of perhaps one six-thousandth of a second separated by variable spaces of about one one-hundredth of a second. These peaks are so short that the various reflections are always completely resolved, and all ambiguity is eliminated. Evidences of a rapidly varying polarization of the different waves arriving at the receiver have been obtained and will be further studied.

: EFFECT OF PRESSURE ON THE CRITICAL TEMPERATURE OF MAGNETIZATION

The preparation of manuscript and graphs giving the results of this investigation by Adams of the Geophysical Laboratory and Green of the Department has been interrupted by the investigations on marine earth-inductor studies by Green for application on Cruise VII of the *Carnegie*. This delay was opportune, however, as Gibson of the Geophysical Laboratory, who has been investigating the thermal condition of the bomb used, found certain systematic errors over the pressure-range of 400 to 600 atmospheres for the platinum-rhodium thermocouple. The application of corrections for these errors as determined by Gibson, using other thermocouples, shows the abrupt depression of critical temperature of magnetization between pressures of 400 and 1,000 atmospheres for the different metals indicated by the original experiments is greatly reduced and indeed disappears for some of the metals used. Thus the conclusion already indicated (see pp. 191 and 226 of annual report for 1925-26) are not changed in character but are strengthened.

EXPERIMENTAL WORK IN TERRESTRIAL ELECTRICITY¹

The observations, developments of methods, investigations and discussions by Mauchly, Gish, Wait, Rooney, Sherman and temporary assistants Frederick and Strohman, in the Section of Experimental Work in Terrestrial Electricity are summarized below.

Atmospheric electricity—Registration of potential gradient and negative conductivity was continued throughout the year on the deck of the laboratory, Sherman attending to the routine of this work. Factors for reducing the measured potentials to volts per meter over a plane area were determined on five occasions on eight days by Wait, Sherman, Ledig and Eaton. Critical studies of the records from the observatories with a view to ascertaining the performance of instruments, laboratory tests bearing on such matters, and suggestions for improvements were made by Mauchly, Gish, Wait and Sherman (see p. 255). Some counts of nucleation-centers including a continuous 24-hour series were made by Wait, Parkinson and Sherman.

¹ From report for the section by O. H. Gish, acting chief of section, and subreport by G. R. Wait.

A considerable portion of the time of Gish, Wait and Sherman was given to experimental work concerned with outfitting the *Carnegie* for her seventh cruise; Rooney also occasionally assisted in this. Huff contributed in large measure to development of designs and construction to accomplish the desiderata indicated by theory and experimental results. Equipment was developed for obtaining continuous photographic records of the atmospheric potential-gradient. The instrument for measuring the ionic numbers was improved by substituting a constant-speed electric motor for the spring motor and several minor features were designed to improve the insulation. The apparatus for measuring penetrating radiation was overhauled and a stabilizing condenser with suitable adjustments adapted to it. The equipment for determining radioactive content was redesigned and made into a portable unit which could be operated at various points on deck. An improved equipment was installed for obtaining eye-readings of conductivity; an apparatus for recording this element was designed and one is now under construction. Improvements in the general assembly on the vessel for convenience and greater security from insulation-difficulties and for protection of batteries were designed. Various tests and determination of constants were made in the laboratory and ten days were spent on the vessel by Gish and Wait in further adjustments and the evaluation of such constants as the factor for reducing the potentials measured on the *Carnegie* to volts per meter over a plane area and the so-called Eve's constant for the penetrating-radiation apparatus as mounted during observation.

Sherman made up the large supply of string-electrometer and galvanometer elements required for use at the observatories and on the *Carnegie*.

Analyses of penetrating-radiation data from all cruises of the *Carnegie* were made by Gish and Frederick, and ten 24-hour series of observations at the top of the Washington Monument were carried out by Frederick (see p. 255).

Earth-currents—The discussion of the first six months' records with the new electrode-system at Watheroo indicates decided improvements with this new arrangement and promises an accuracy in diurnal variations of this element comparable with, if not surpassing, that obtained for any associated phenomena. Studies were made of the earth-current records by Gish and Rooney for the purpose of determining the magnitude and source of errors (see p. 256). It was found that an error apparently associated with temperature entered in some way directly at the electrodes and that this is eliminated by the new electrode-arrangement. Analyses of variations in earth-current potentials at Watheroo and comparisons of these with the magnetic elements recorded there as well as with records of earth-currents at other places were also made and a paper was prepared by Gish and Rooney on part of this work (see p. 256).

Methods and equipment designed for measuring marine electric currents for use on the *Carnegie* were developed and preliminary tests were made by Gish and Frederick near Solomon's Island. This equipment was also tested by Gish on the return of the *Carnegie* from New York to Washington.

Preliminary trials of an induction-method to measure earth-currents were made by Gish and Frederick. Although the method is obviously difficult, in the present stage of laboratory-tests, it appears feasible for use in checking the earth-current densities deduced from earth-current potential measurements and earth-resistivity, as well as for detecting a constant component of the earth-current if this is not of a lower order of magnitude than the observed variations.

Earth-resistivity—Early in the present report-year improvements were added to the earth-resistivity apparatus to eliminate disturbances which arose from insulation-leak in the more difficult measurements. These were tested and found to completely eliminate such effects.

Through a cooperative arrangement with the Michigan College of Mining and Technology, surveys were made by Rooney and Strohman in the Michigan copper country near Houghton. These afforded checks on the interpretations as regards the depth of ground-water and other hidden structures, and provided additional data regarding the resistivity of constituents of the Earth's crust (see p. 262).

At the request of the Bureau of Standards, a comparison of the McCullum earth-current meter with the Gish-Rooney earth-resistivity meter was made. Arrangements were made for carrying out resistivity-surveys in cooperation with the United States Bureau of Mines during the summer and autumn of 1928. Increasing interest has been manifested in the earth-resistivity method as a means for locating deposits of minerals concealed in the Earth's crust.

Miscellaneous—The interest in terrestrial electricity and its investigation, indicated by the many scientists visiting the laboratory and the many letters received, is worthy of note. The data requested and supplied included, for example, electrical character of certain periods during which radio communication was disturbed, values of earth-resistivity, details of design for instruments used in atmospheric-electrical measurements.

Tests were made for the United States Public Health Service of the charges acquired by certain insecticides when these are dispersed in air, and the possible effect of these upon the distribution of such materials when dusted from aircraft was discussed with Dr. L. L. Williams jr. of the Service, and also with Mr. H. R. Harris, Manager, of Huff Daland Dusters, Inc.

Radioactive collectors for measurements of atmospheric potential-gradient were supplied to several foreign investigators and organizations planning to study and use the Department's design of collector.

The requests for details of construction and operation of the Gish-Rooney resistivity-equipment have been especially numerous. At the present time there are at least six of these outfits constructed or in process of construction for use in the study of underground structure.

Publications—Gish read a paper before the joint meeting of the sections of Terrestrial Magnetism and Electricity, of Seismology, and of Geodesy of the American Geophysical Union, April 26 on "Depths of ground-water and some geological features indicated by earth-resistivity surveys." Gish and Rooney prepared a paper entitled "On earth-current observations at the Watheroo Magnetic Observatory, 1924-1927." Rooney prepared a paper "Earth-resistivity measurements in the copper country, Michigan" and gave a report to the Pick and Hammer Club, November 19, on "Earth-resistivity measurements and their bearing on the location of concealed geological discontinuities." Abstracts of these and other investigations partially completed are given on pages 253, 256 and 262 of this report. .

FIELD WORK AND REDUCTIONS

DEVELOPMENTS AND IMPROVEMENTS FOR FIELD AND OBSERVATORY
INSTRUMENTS

As might be expected the instrumental equipment for the *Carnegie* has called for intensive application on the part of the entire staff. Progress was made in the application of electromagnetic methods for magnetic determinations on board. This problem has had the attention of Soule, Green, Peters, Fleming and Huff and the results obtained so far during Cruise VII indicate entire success for the determination of inclination by the marine earth-inductor. The application of the inductor to the determinations of intensity to which Soule has also given particular attention is not yet solved. Provision having been made to drive the coil by a constant-speed, tuning-fork-controlled motor, the determination of intensity requires (1) determination of resistance of circuit, (2) means to read with sufficient accuracy a milliammeter, (3) maintenance of proper position of the rotating coil with respect to the Earth's field in spite of the motion of the ship, and (4) knowledge of dimensions of coil. Special circuit-connections with a testing-set provide means for rapid determinations of resistance during observation. To meet (2) Soule designed a large inductance of two coils mounted on opposite legs of a closed magnetic core of Hypernik for connection in series to smooth out fluctuations in the current. For (3) the attempt is being made to attain the required stability gyroscopically, the instrument being mounted on the frame of a non-magnetic gyrostat-swing on the double reversible gimbal-system, used on previous cruises of the *Carnegie*, and driven through a universal joint and gears from the same constant-speed shaft that is used to drive the inductor-coil. The dimensions of the coil are numerically determined by measurement and the finer corrections are obtained through calibration of the coil against magnetometer-measurements or at a place of known magnetic intensity. Experimental work on this application is being continued on board the vessel. Meanwhile intensity-determinations are made also by use of the C.I.W. deflector used on previous cruises. The other standard magnetic instrument is the C.I.W. marine collimating-compass, the efficiency and precision of which were evidenced in earlier cruises.

The atmospheric-electric equipment for the *Carnegie* has received careful study and has been improved in many details. Gish, Huff, Parkinson and Wait have been responsible for the new developments, particularly the electrograph using ionium collector for continuous photographic registrations of atmospheric potential-gradient, which is controlled by the eye-reading apparatus used on previous cruises, and improved conductivity apparatus. The latter installation is at present arranged for eye-readings, but a photographic attachment is being prepared for installation later to permit continuous photographic registration of conductivity. This apparatus is of the same type as used at the Department's observatories (see pp. 303-304 of annual report for 1922) with the exception that on board ship the quadrant-electrometer system had to be replaced by a single-fiber electrometer of suitable sensitivity. The new equipment also includes an Aitken dust-counter with which observations are to be made regularly on board

to obtain data for correlative studies with atmospheric electricity and possibly to determine a standard dust-count for unpolluted air.

The electrical salinity-apparatus after the design by Wenner of the United States Bureau of Standards was devised and constructed by Huff in the instrument-shop. The equipment was found quite satisfactory upon test by Soule, and the results already obtained on board fully justify its application in oceanographic studies.

COOPERATION WITH OTHER ORGANIZATIONS

The cooperation program with the Mount Wilson Observatory has been continued and a declination-variometer was supplied by the Department for the variation-observatory there; thus continuous photographic records of both magnetic horizontal intensity and declination are now obtained at this station.

The plans for an atmospheric-electric building at the Tuscon Magnetic Observatory have been kept in mind and through the cooperation of the United States Coast and Geodetic Survey it is now expected that these plans may be realized within the next year. The cooperation between the Department and the Division of Terrestrial Magnetism and Seismology of the United States Coast and Geodetic Survey referred to in the last year's report (p. 177) continues to be of mutual benefit. It is valuable also in planning for the most advantageous program of investigational work to eliminate any duplication of effort. The program with the Michigan College of Mining and Technology on the application of geophysical methods to determine geological formations was followed out with excellent results (see p. 257). Arrangements were made for similar cooperative programs in the field in 1928 with the Bureau of Mines of the United States Department of Commerce.

Cooperation looking to the securing of additional magnetic and electric data in the polar regions was effected by the Department with General Nobile's Arctic Expedition and with the Byrd Antarctic Expedition. The necessary curtailment of our land work has found some compensation in the arrangements made for cooperation of the Department with others in securing additional observations where needed for secular-variation studies. Thus the University of Cape Town has joined in the survey of the southern part of Africa (see p. 223).

Many requests continue to be received from all parts of the world for accumulated magnetic data for both theoretical and practical application. Naturally the interest in possible applications for the study of underground structures, in view of the world-wide intensive development of oil-fields, has been much evidenced.

The cruise of the *Carnegie* has also brought out opportunities for cooperative work with many organizations. Thus the Geophysical Laboratory of the Institution is especially interested in the bottom-samples to be obtained, the results of the analyses of which promises valuable additions to the knowledge of the Earth's crust; Zies and Posnjak hope to make X-ray and chemical analyses of the samples at the Laboratory. The United States Navy Department through the National Research Laboratory has aided

in the design and installation of experimental radio sending and receiving equipment, which in connection with a schedule of communication to be maintained with the Laboratory and radio amateur stations of the American Radio Relay League, already has yielded data for radio investigations.

The preparations for Cruise VII of the *Carnegie* have had generous cooperation and expert advice on all sides from interested governmental and private organizations and individuals both in America and Europe, who have either loaned or presented much of the special oceanographic equipment and many books for the library on board. Among these the Institution is indebted to the following: United States Navy Department, including particularly its Hydrographic Office and Naval Research Laboratory, Signal Corps and Air Corps of the War Department, Coast Guard, National Museum, Bureau of Fisheries, Weather Bureau, and Coast and Geodetic Survey; Scripps Institution of Oceanography of the University of California; Museum of Comparative Zoology of Harvard University; School of Geography of Clark University; American Radio Relay League; Geofysisk Institut, Bergen, Norway; Marine Biological Association of the United Kingdom, Plymouth, England; German Atlantic Expedition of the *Meteor*; Institut für Meereskunde, Berlin, Germany; British Admiralty, London; Carlsberg Laboratorium, Bureau International pour l'Exploration de la Mer, and Laboratoire Hydrographique of Copenhagen, Denmark; and many others.

Various conferences for discussion of the proposed programs of observations for the *Carnegie* have been held during the year. At all of these suggestions and constructive criticism have been generously given by individuals and organizations interested in the development of various fields of activity. Seiwel spent some months (September to December) at the Scripps Institution for Oceanography, La Jolla, California, where the privileges of the Institution were freely extended him by Dr. T. Wayland Vaughan, Director, and various members of the staff. A special conference on evaporation was arranged by Dr. McEwen at the Scripps Institution to discuss program for such work on the *Carnegie*. While en route from La Jolla, Seiwel visited the Hopkins Marine Station at Pacific Grove and Stanford University. As a result of his studies and conferences Seiwel prepared and submitted a proposed biological and chemical program (see p. 263).

OCEAN WORK ¹

VESSEL MAINTENANCE

The repairs and overhaul of the *Carnegie* were satisfactorily completed by the Tietjen and Lang Dry-Dock Company in Hoboken, New Jersey, under Ault's supervision. The 15-horse-power electrically driven winch, 12-kilowatt generator, and 25-horse-power gasoline engine were installed. A sonic depth-finding apparatus loaned by the United States Navy Department was placed on board, the oscillator being appropriately mounted on the hull below the water-line. The main auxiliary engine was extensively overhauled. Upon the completion of repairs to the hull in dry-dock and of the general overhaul, the vessel left Hoboken under tow of the United States Coast guard tug *Manhattan*, October 12, 1927, reaching the mouth of the Potomac River on October 15. She was brought to Washington October 17

¹ From the report of the chief of section and commander of the *Carnegie*, J. P. Ault.

by a local tug. During the trip the new engine, motor-driven winch for oceanographic work, sonic depth-finder, thermographs for recording surface-temperatures, "Divinhood," and new arrangements for handling life-boats were tested. Some experimental work was done also by Ault, Gish, Parkinson and Huff.

During the winter the many details required for final instrumental and electrical installations were completed. In this Huff gave invaluable assistance, particularly so in the electrical equipment and circuits which, because of the extensive application of electric current in the proposed program, were quite complicated. At Washington a galvanometer-house was added to the deck-structures built at Hoboken, namely, the radio laboratory and the oceanographic laboratory.

PREPARATIONS FOR CRUISE VII

The preparations for the three-years' cruise of the *Carnegie* were completed in accordance with the plans as outlined in the reports of the two previous years. The equipment necessary for the extensive program as listed in last year's report (p. 178) was received in time to permit beginning the cruise from Washington as planned on May 1, 1928.

No small part of the preliminary arrangements were concerned with the preparation of detailed forms and instructions to make possible the carrying on of so large a program by the relatively small number of the scientific staff. Thus, extended tabulations were compiled to reduce to a minimum the time required for computations; numerous new forms were developed to facilitate and systematize the entry of observational data; shorter methods of computing than those used on previous cruises were developed for some of the observations.

PROGRESS-REPORT CRUISE VII MAY AND JUNE 1928

The following extracts from Captain Ault's reports abstract the progress made on Cruise VII to June 30, 1928.

The seventh cruise of the *Carnegie* began when the vessel left the wharf at the foot of Seventh Street, Washington, under tow at 9^h May 1, 1928. Shortly after midnight on May 2 she came to anchor at the mouth of the St. Mary's River for the swings in the lower reaches of the Potomac. Six swings under her own engine were made to detect any deviations in declination or horizontal intensity, while potential-gradient comparisons were made May 3 and 4 with the shore-station, as well as experiments to test the marine earth-inductor and the radio installation. A swing was made under her own engine in the morning of May 5 to detect any deviations in dip and intensity and complete potential-gradient comparisons were then made at anchorage. Simultaneous shore-observations were made during all swings and comparisons. The *Carnegie* proceeded then to Newport News, arriving May 6 for docking and adjusting the oscillator of the sonic depth-finder.

Leaving dry-dock at 11^h May 10 the *Carnegie* was towed out into Hampton Roads and late in the afternoon cast off the tug and set sail while still in the entrance of Chesapeake Bay, taking a departure from Cape Henry at 18^h 20^m.

From there until arrival at Plymouth, England, weather conditions were rather unfavorable—strong winds, heavy seas and cold and rainy weather. The course as planned was followed fairly well for the first two weeks, but

during the last two weeks adverse winds were experienced. The vessel was held off the entrance to the English Channel for ten days by easterly and southeasterly winds and gales.

Declination (*D*) observations with marine collimating-compass were made at 29 stations, and horizontal intensity (*H*) with deflector and inclination (*I*) with earth inductor at twelve stations. Chart-corrections ranged from $+1.0$ to -0.8 in *D*, from $+0.002$ to -0.005 C. G. S. in *H*, and from $+0.9$ to -0.7 in *I*. All magnetic instruments worked well. The maximum range in the inclination for a single station did not exceed $30'$ as determined with earth-inductor 7 using improved gimbal-ring mounting (not gyro) and microammeter without amplification. At all but three stations experimental determinations of *H* were made with the same method; vertical intensity (*Z*) was determined also at a number of stations.

The atmospheric-electric program was carried out as completely as was possible, but the limitations of time and breaking in of new personnel did not permit using the radioactive-content apparatus. The masthead mounting for the photographic potential-gradient electrograph was found impracticable because of the great play of the masthead in moderate and rough weather; experiments were then begun to find a suitable location for use.

Six ocean-stations for securing temperature and water-sample series were occupied, conditions of sea and weather not being favorable for stopping the vessel on other days. All the equipment, winch, water-bottles and deep-sea reversing thermometers, both protected and unprotected, worked excellently. The unprotected thermometers, calibrated for pressure, gave excellent control of the actual depths reached. Usually, owing to a stiff breeze, the wire-angle at the surface was very large, so that some control of the depth was very necessary.

The tow-nets were operated at eight complete stations, and surface-tows were made at 50 stations. Whenever the vessel was hove to or under slow headway, advantage was taken of the opportunity to secure surface-tows and dip-up specimens with dip-nets. Many collections were made at night using the under-water light. The large meter-nets were not used except on one or two occasions, awaiting the devising and construction of heavier releasing devices.

The salinity-bridge was in successful operation from the first, and salinities are usually available on the day following the occupation of an ocean-station.

The depth-finder was used at 57 stations. Unfortunately, it was not possible to check its accuracy with wire-soundings, but in shallow water the results agreed to within one fathom of the chart-values.

Daylight-contact with radio station NKF (U. S. Naval Research Laboratory at Anacostia, D. C.) failed early in the trip; it is hoped that a more extensive schedule, including one at night, may be arranged later. Good contact was maintained with station 1MK at Hartford, Connecticut, U. S. A., throughout the trip, with one or two exceptions.

The ship has been kept up in as good condition as was possible, in view of the almost continuous bad weather. The small engine and generator worked well and frequent use was made of the main engine during calms and to get eastward against the head-winds. The new arrangements for life-boats and new laboratories were found to cause too heavy strain on the chart-room due to lateral thrusts from life-boat platforms, and consequent flooding of the cabin and staterooms. The accumulation of water on the main deck naturally was troublesome. The heavy weather also started the copper

sheathing to peel off in many places along the water-line. In general, the vessel labors and works less than heretofore, in spite of being very heavy and low in the water aft. The quarter-deck was awash many times during the trip across, something which has happened very rarely in past cruises. The rigging kept fairly taut and in good condition.

After the ten-days' delay with head-winds, the vessel was within a few hours sail of picking up the first landfall at Bishop Rock, Scilly Islands. Then it began to rain, fog and mist closed in, and it was necessary to stand off to sea again. After several hours, it cleared up enough to head for the light, which was picked up at midnight. A fine fair wind then held to within ten miles of Plymouth, when it began to rain, mist and fog set in, the wind hauled ahead, and we were on the point of heading back to sea again, when the headland was sighted June 8 two miles west of Plymouth Harbor. After taking in square-sails, the engine was started and way made to port against a rising gale, with only one hour of daylight remaining. The pilot was found awaiting inside the harbor when the vessel had already gained a safe position near the breakwater. The new cable for the port anchor was so stiff and hard and wet from continual bad weather that it kinked and could not be let out rapidly enough to fetch the vessel up against the gale. The starboard anchor was let go just in time to avoid danger, and the vessel remained at anchor until taken to the well-sheltered inner harbor the next morning. For the next 36 hours a terrific gale blew from southeast to southwest which would have sent us hurrying back to sea again for another week if we had been lucky enough to weather the confines of the channel.

At Plymouth supports were installed under the inboard ends of the cross-beams which support the boat-platforms to take the weight off the chart-room and laboratories. Full advantage of the call at Plymouth was taken for conferences with Dr. Harvey and Dr. Atkins and their colleagues at the laboratory of the Marine Biological Association on the biological program. Seiwel observed the collecting methods employed by the Plymouth Laboratory during a short trip on the Association's ship *Salpa*. A visit was made to the National Physical Laboratory at London to secure calibrations for the salinity-apparatus.

The *Carnegie* left Plymouth at 16^h 30^m, June 18, being towed 15 miles off shore until sails were set, and with a fair wind proceeded up the Channel all night. The engine was operated the next day because of light winds and calm. During the night of June 19, the *Carnegie* passed through Dover Strait with favorable wind and tide; fortunately there was no fog, and conditions were excellent. Soon after leaving the Strait, the wind hauled ahead, however, and it was necessary to operate the engine practically continuously through the North Sea.

After making successful landfalls along the Dutch and German coasts approaching the Elbe River, and when within three hours' sail of the mouth of the River, fog and mist and rain set in, making it impossible to sight the two lightships which point the way to the mouth of the Elbe. By keeping on and watching for the traffic route as indicated by glimpses of steamers passing to southward in the mist, the ship gradually headed up against the strong flood-tide and finally made out the pilot-vessel during a temporary lifting of the fog. The engine again proved its value and assistance, taking the vessel up the river against head-winds and calms, until meeting the tug-boat (ordered from Hamburg the previous night) while passing Borkum Riff lightship. Dr. H. U. Sverdrup of the Geophysical Institute in Bergen,

Norway, and Research Associate of the Department, was on the dock to meet the party, when the *Carnegie* reached Hamburg June 22 at 19^h 30^m, a little over four days out of Plymouth.

Surface-tows were made and samples taken at 33 stations in the English Channel, Dover Straits, and the southern North Sea to the mouth of the Elbe River, and analyzed for phosphates, H-ion concentration, and salinity. Two surface-tows were also made as the vessel proceeded up the Elbe River to Hamburg. Magnetic declination, inclination and horizontal intensity were determined at two sea-stations between Plymouth and the mouth of the Elbe River.

The cordial welcome and interest accorded the party at Plymouth was repeated at Hamburg, German scientists being especially enthusiastic regarding the program and equipment. Some preparation had been laid for the visit through the advance work done by Sverdrup, when he presented in May an account of the *Carnegie's* program and plans at the centennial celebration of the Geographical Society of Berlin. Ault, upon request of the Society, also gave an illustrated talk June 27 at a special meeting of the Society in Berlin on the progress of the Cruise, his paper being preceded by a brief summary by Sverdrup.

At Hamburg, following extended conferences with the staff of the German Admiralty under President Vice-Admiral Dominik and of the Oceanographical Institute of Berlin under Director Dr. Defant, some changes were made and some additional equipment was placed on board. The experience of Dr. Defant and colleagues in the South Atlantic on the recently completed cruise of the Institute's ship *Meteor* was the basis of some rearrangements for the oceanographic and meteorological program. Both the Admiralty and the Institute most generously gave up new equipment, only recently received by those organizations, to make possible installations during the stay at Hamburg. Hartman and Braun completed most satisfactorily the installation of the electrical temperature-recording apparatus with wet- and dry-resistance units at masthead, on cross-tree and in meteorological shelter-house on the quarter-deck. The plankton-catchers constructed under the direction of Dr. Pettersson of Copenhagen were also placed on board at Hamburg, Sverdrup having made a test of these at Copenhagen in May. There was also delivered to the *Carnegie* by Dr. Kolhörster at Hamburg a penetrating-radiation apparatus, after his design, for possible comparisons with the *Carnegie's* apparatus.

While in Hamburg the vessel was dry-docked to make repairs and to strengthen certain structural details which had been so severely tried during the heavy weather just before reaching Plymouth. The new installations and repairs being completed and tested the *Carnegie* left Hamburg on July 7 for Reykjavik, Iceland.

The total personnel aboard is 25. The scientific staff of eight as now constituted includes: Captain J. P. Ault, commander, and chief of scientific staff; Wilfred C. Parkinson, senior scientific officer (atmospheric electricity and photography); Oscar W. Torreson, navigator and executive officer (magnetism, navigation and meteorology); F. M. Soule, observer and electrical expert (magnetism and physical oceanography); H. R. Seiwel, chemist and biologist (oceanography); J. H. Paul, surgeon and observer (medical work, meteorology and oceanography); W. E. Scott, observer (magnetism, navigation, and commissary); Lawrence A. Jones, radio operator and observer (radio investigations and communications, and magnetism). We are for-

tunate in again having obtained the services of three officers of the sailing staff who were on board the entire two years of the last cruise of the vessel, namely, A. Erickson, first watch-officer, C. E. Leyer, chief-engineer, and F. Lyngdorf, steward; E. Unander is second watch-officer, and H. Jentoft is third watch-officer.

LAND MAGNETIC SURVEY¹

The necessity of concentrating all the resources available for survey-work upon the preparations for Cruise VII of the *Carnegie* has made it impossible to initiate any new undertakings in the land survey. One expedition, that of Sanders to Africa was brought to a conclusion during the year; further work there, however, in continuation of the Department's secular-variations program was initiated in cooperation with the University of Cape Town. The Department of Physics of that University has put an observer in the field during the vacation and will follow the same practice with regard to program of observations and distribution of repeat-localities, as had been proposed for the Department's survey. During the past year Sanders had completed the work in Belgian Congo and that in Angola. In order to arrive at Cape Town by the first of December in time to make the necessary comparisons there with the instruments loaned by the Department for the use of observer E. N. Grindley of the University and to give him instructions in our methods, the proposed stations in Southwest Protectorate and western Cape Colony were omitted. During the vacation-period, December 1927 to March 1928, Grindley observed in eastern Cape Colony, and during the short vacation in June to July he planned to observe at a few points in Natal. The program of diurnal-variation observations at selected places at distances of approximately 500 miles was continued with gratifying results, although Grindley found difficulty in working with the earth inductor at some of his stations because of the accumulation of electric charges on the walls of the tent during the season of high winds and very dry dusty atmosphere.

REDUCTION OF LAND OBSERVATIONS

The necessary office revisions of field-observations have been kept current, those which have been received from the observers having been made ready for publication, except for the application of the final corrections required to reduce the results to the adopted International Magnetic Standards.

COOPERATIVE WORK

The arrangement for cooperative work with the Government Astronomer of South Australia has been continued, though no results have been communicated by him within the year. The two vessels of the United States Navy engaged in hydrographic survey-operations have continued the arrangement for cooperation with the Department in securing magnetic observations, which existed in the previous year. Lieutenant (jg) H. B. Southworth superseded Ensign Latimer in charge of the magnetic work on the U. S. S.

¹ From the report of the chief of section, H. W. Fisk.

Niagara, and secured observations at four stations on and near the north coast of Cuba; Lieutenant (jg) R. F. Stout was assigned to the similar position of the U. S. S. *Nokomis* previously held by Lieutenant (jg) Courts, and made observations in the gulf of Panama. A dip-circle specially fitted for observations in polar regions and specific directions for its use were supplied the arctic expedition of General Umberto Nobile, on the possibility that conditions would permit securing some observations during his explorations in the Arctic Ocean from Spitsbergen. Complete outfits for a temporary variation-observatory, and for absolute observations at the base-station and for observations at field-stations on exploratory sledge-trips have been put under way for cooperative work with the Byrd Antarctic Expedition. The necessary standardizing observations were begun in June, preliminary to the training of the observers R. F. Shropshire and F. T. Davies in the use of these instruments and the reduction of the results. An arrangement for cooperation in the continuation of the land survey of the southern part of Africa was completed with the Department of Physics of the University of Cape Town. The observer, E. N. Grindley of the University, made observations at about fifteen localities during December 1927 to March 1928 and a few additional stations in June and July. Arrangements were completed whereby Odd Dahl, assistant physicist of the Department, while on furlough and making an exploratory expedition to the central part of Asia, will secure observations beginning in July 1928 in Syria, Persia, Turkestan, and possibly portions of India and European and Asiatic Russia.

FIELD-OPERATIONS

The land work done during the year is summarized in the following abstract of reports on such work:

Africa—During the year the expedition by Sanders, begun in May 1925, was terminated and he returned to Washington about the middle of February. The entire expedition therefore covered a period of a little less than three years, in which time reoccupations of stations were made in the Canary and Madeira islands, along the western coast of Africa from Morocco to Cape Town, and inland along such routes as offered facilities for travel without excessive cost or the loss of a disproportionate amount of time. The inland routes included notably a rail and river expedition from Dakar to Kayes in Senegal; a more extended expedition from Conakry to the headwaters of the Niger River, thence down that river through French Soudan, to the northern part of Dahomey, and thence overland to Cotonou; the ascent of the Benue River in Nigeria to Garoua, Cameroun, returning to the junction of that river with the Niger, and going thence by rail to Northern Nigeria to Kano, and eastward overland by motor to Lake Tchad; and finally the route along the Shari, the Ubangui and Congo rivers to Boma which had brought him to the Belgian Congo at the end of June 1927. In 1914, Wise of the Department had crossed that colony by an overland route from Elizabethville by way of Lusambo and Luebo to Kwamouth on the Congo. It therefore was very desirable to reoccupy a sufficient number of stations within the great area traversed by the Kasai River and its tributary, the Sankuru River. Sanders left Basongo May 10 and arrived at Luebo June 7; he began the trip up the Sankuru for Lusambo June 30. This journey

was slow and difficult, with no opportunity for work at intermediate points, and it was not until July 16 that the river steamer reached Lusambo, though the distance in a direct line is scarcely 250 miles. The return down the Sankuru and Kasai rivers was more rapid but equally dangerous, serious disaster having been met by the steamer on a subsequent trip, though Sanders came through successfully. Kwamouth was reached August 7. After repeating observations at this place on August 8 and a short trip up the Congo to Bolobo, where the station of Wise in 1914 and of Sawyer in 1916 was reoccupied, with auxiliary stations, Sanders descended the river to Boma which was reoccupied a second time, his former visit having been before the Kasai trip on May 2 to 4.

In 1915 Wise had traversed the west coast of Angola, or Portuguese West Africa, and in 1916 Sawyer had visited a few of the same points on his way to French Equatorial Africa. In 1920 Brown had crossed the continent from west to east, entering at Benguella on the west coast of Angola. With this as a foundation, Sanders, after leaving Belgian Congo, began a series of reoccupations for secular variation in that country. Communication along the coast from colonies of other countries is very irregular and uncertain, and considerable time was lost in securing transportation between ports. He also found it necessary to overcome some reluctance on the part of the officials, due to some unfortunate incidents which occurred before his arrival. The existence of a railroad extending inland from Loanda, and of a longer one designed to provide an outlet from the region between Elizabethville and the Portuguese border to the sea at Benguella, facilitated movement within the country so that a very satisfactory series of reoccupations was secured. Leaving Banana, Belgian Congo, August 25, he arrived at Lobito four days later, and started inland over the railway to Moxico, reoccupying stations previously visited by Brown in 1920 and by Wise in 1915, before the railroad extended so far inland as at present. Returning to Lobito, he took passage to Loanda, this retracing his route northward being required by the available transportation. A shorter rail trip to Malanje was made from Loanda late in October to repeat observations made by the observers of the Institution in 1915 and 1920. After a stop at Mossamedes, Sanders went direct to Cape Town where his field-work was concluded.

In 1903 and subsequent years through 1912, Dr. J. C. Beattie (now Sir Carruthers Beattie) had made a complete magnetic survey of southern Africa, assisted during 1908 and 1909 by a cooperative arrangement with the Department. Only a few widely scattered observations have been made in that general region since that survey and, because of the very rapid changes known to be taking place in the magnetic distribution there, the reoccupation of selected secular-variation stations had become very desirable. Realizing this urgent need, Professor A. Ogg, of the Department of Physics of the University of Cape Town, suggested that the Institution again cooperate in securing the desired observations. An arrangement thereupon was effected by which a magnetometer-inductor was loaned to the University of Cape Town and a small grant against part of the traveling expense of the observer was made. E. N. Grindley, an assistant in the Department of Physics in the University, was designated by Professor Ogg as the observer to undertake the work, after receiving instruction in the methods and field-practice of the Department from Sanders at Cape Town.

Sanders devoted the month of December to giving such instruction to Grindley, making complete reoccupation of the stations at Cape Town, and in comparing with his own the instrument supplied for the use of the Uni-

versity. Grindley left Cape Town at the end of December and devoted the following two months to reoccupying stations in Cape Colony and Orange Free State, going eastward to East London and northward as far as Bloemfontein and Karree, Orange Free State; a total of fifteen localities was occupied with auxiliary stations at five of these. A short vacation-period permitted Grindley to reoccupy a few stations at the beginning of July; he accordingly left Cape Town June 26, intending to reoccupy stations near Durban, in Natal, and Bethlehem, Orange Free State.

The practical demand for this new magnetic survey is illustrated by a quotation from a circular issued to its members by the Aero Club of South Africa submitted by Grindley with his report. The circular says in part: "A fresh magnetic survey has recently been begun by the Physics Department of the University of Cape Town. Through the courtesy of the University authorities the following information has been obtained for the benefit of air pilots. Compass variation (west) has decreased more rapidly since 1903 than would have been predicted from the information then available. This decrease gets steadily greater . . . as one moves from west to east. Thus the decrease at Cape Town is $4^{\circ}0'$. . . , at East London it is $5^{\circ}4'$, while in Natal it may be expected to be $6^{\circ}0'$. . . , and in Northern Rhodesia about $4^{\circ}5'$. . . The figures given are . . . from results of actual observations by E. N. Grindley of the Physics Department, University of Cape Town, and from predictions made by him from a sketch-map supplied by the Department of Terrestrial Magnetism, Carnegie Institution of Washington, in conjunction with which Department the present survey is being carried out."

In addition to this unusually rapid change in the rate of secular variation in declination in going eastward alluded to in the quotation, there is an equally remarkable change in the rate of secular variation in horizontal intensity as one approaches the southern end of the continent from the north. At Cape Town and stations in the general vicinity, that component has decreased more than 15 per cent since 1900, and the present rate of decrease seems to be greater than it was 20 years ago, being not far from 120 gammas annually. At Mossamedes, Angola, which is the nearest station north of the area for which recent observations are available, the annual rate is not in excess of 50 gammas.

The work of Sanders and Grindley so far as it is available for consideration shows the existence, as was suspected, of a center of rapid annual-change of each of the elements in Africa or the waters immediately adjacent. That for declination lies in Rhodesia, where the maximum change may reach as high as $15'$. Stations in Orange Free State show in excess of $13'$, and it is probable that the maximum lies farther north and is therefore somewhat greater. The annual change in inclination increases steadily from central Africa westward along the Guinea coast until it becomes $15'$ or more in Liberia and Sierra Leone. The general trend of the lines of equal change indicates the center somewhere in the ocean between St. Helena and the Cape Verde Islands. Observations by the *Carnegie* as discussed by Ault show changes of $16'$ to $18'$ in that area. As has already been indicated, the maximum change in horizontal intensity lies below Cape of Good Hope. That element is increasing very slightly in the vicinity of Lake Tchad, while along the Congo River the change is decreasing and the rate of decrease increases steadily toward the south, until the very rapid rate approaching 120 gammas annually is shown for the extreme southern part of the continent.

The discussion has not been carried sufficiently far to show what the character of the acceleration is in the various parts of the continent covered by the recent survey. Whether the concentric ovals, representing the lines of equal annual-change in the case of each of three elements, are decreasing in diameter, as has been shown to be the case of similar lines in South America, or whether they may be increasing can not be determined by the observations so far at hand. Observations are to be made during the coming year in southeastern Africa, which should lie east of the center of most rapid change in declination. These with others in Southwest Africa, combined with those already made in Angola west of this center, should answer that question so far as the declination is concerned. For the other two elements—the inclination and the horizontal intensity—the centers apparently lie in the oceans, where observations of the requisite accuracy can scarcely be looked for. The rate of change of the inclination in Liberia and Sierra Leone was larger than was forecast from available data at the time of undertaking the present survey, and this may be taken to indicate an increasing rate in that region, though, it must be remembered, data for any reliable conclusion were very meager. A similar remark may be made to apply for the rapid rate of decrease of horizontal intensity in the extreme south, though here the forecast was nearer the result indicated by observations so far at hand.

Asia—An expedition under the leadership of Dahl has gone into central Asia for scientific and exploratory work, and includes in its plans making repeat-observations in Syria, Persia, Turkestan and northern India. Observations were made by the Department in these regions during 1908 to 1910 and a short expedition in 1922 repeated a few of these in Syria and Palestine. Some observations by other organizations are available for limited localities, but in general little recent work has been done that can be utilized for secular variation in this area. It is hoped that Dahl's results may be numerous enough to aid materially in the discussion of magnetic changes there.

Australasia—Aside from the continued operation of the Watheroo Magnetic Observatory, nothing has been done in Australasia.

Europe—During the stay of the *Carnegie* at Hamburg, Germany, comparison-observations between the standard of the Potsdam Observatory at Seddin and those of the Department were made June 27 to 30, 1928, by Parkinson. Thus a valuable check-series has been added to the coordination of magnetic standards which will be a feature of the *Carnegie's* future work on Cruise VII.

North America—The United States Navy has undertaken to increase the amount and scope of the magnetic work done by its parties engaged in hydrographic surveys and has invited this Department to cooperate. This has been done by giving instruction to the officer of each party in charge of the magnetic work and in supplying some items of the necessary equipment. The U. S. S. *Niagara*, with Lieutenant R. F. Stout in charge of magnetic work, engaged in hydrographic work in the Gulf of Panama and secured a complete series of observations with durnal-variation series in all three elements at Antoine Point, Republic of Panama, latitude $8^{\circ} 17'9''$ and longitude $80^{\circ} 16'5''$ west, during the month of May 1928.

In connection with the preparations of the *Carnegie* for her three-year cruise which was begun May 1, it was necessary to obtain a sufficient number of observations along the shores of the Potomac River, adjacent to the spot in that river chosen for the standardization-observations and swings of the vessel, to make with requisite accuracy the reductions of observations made aboard the yacht. Three observers, Fisk, Green and Kampe, with two com-

plete outfits were in the field engaged in this work from April 17 to May 6. Observations were made not only along the shores of the river but at points several miles inland on both sides of the river, in order to define as well as possible the limits of areas of disturbance which are known to exist over much of Maryland and Virginia. The discussion of these results (see p. 245) gave equations of distribution and a rough approximation of the areas which departed from the uniform distribution, and therefore of the values reasonably to be assigned to the stations on the route of the vessel which were used for comparison with the results by the ship's instruments.

South America—Only the observations necessary to the operation of the Magnetic Observatory at Huancayo were made during the year.

Islands of Atlantic Ocean—One of the hydrographic survey parties of the United States Navy, referred to above, made observations on the north coast of Cuba.

Arctic and antarctic regions—At the request of the Italian government, a dip circle adapted to use for determination of all three magnetic elements in arctic regions was supplied to General Umberto Nobile for use on his expedition to the arctic, should conditions afford an opportunity for making such observations.

A set of instruments was completely standardized in June 1928 by comparison with the Department's standards and assigned for use of the Byrd Antarctic Expedition in a program planned to include absolute observations and observatory registrations, both in terrestrial magnetism and atmospheric potential-gradient.

OBSERVATORY WORK ¹

The work of the magnetic and electric observatories during the year July 1, 1927, to June 30, 1928, may be summarized briefly as follows:

Watheroo Magnetic Observatory, Western Australia—The Watheroo Observatory is in latitude $30^{\circ} 19' 1''$ south and longitude $115^{\circ} 52' 6''$ east of Greenwich, at an elevation of 800 feet above sea-level. The magnetograph was operated continuously and the necessary routine observations for the control of the base-lines were carried out weekly. Complete tabulations of mean hourly scalings were prepared and forwarded to the office for final reduction. Reports of magnetic character of days and descriptions and scalings of magnetic storms and earthquakes were transmitted. The preliminary mean annual values of the magnetic elements as deduced from the magnetograms for all days of the year 1927 are: Declination, $4^{\circ} 16' 3''$ west; horizontal intensity, 0.24671 C. G. S. unit; vertical intensity, -0.51029 C. G. S. unit; and inclination, $64^{\circ} 11' 9''$ south. The preliminary values of the annual changes in the magnetic elements for the period 1926.5 to 1927.5 are 0.9 east in declination, 10 gammas decreasing in horizontal intensity, 22 gammas decreasing numerically in vertical intensity, and 1.2 south in inclination. A time-mark lamp was installed in November. The lamp circuit is closed for three seconds once an hour by means of a program-machine operated by an electric clock. The magnetograms are ready for scaling as soon as they are developed, which is a saving of time as compared with the former time-control method, whereby the positions of the hours were marked by hand from an examination of the time-records which gave the actual times of operation of the shutter.

¹ From the reports of the observers-in-charge.

Automatically recorded differences in earth-potentials were continued. Records are obtained from the original set of electrodes and from another set of electrodes for alternate periods of one month. The original electrodes were placed in sand at varying distances from the surface. At various periods following rain, the natural potentials of the electrodes were affected in different degrees. This caused varying amounts of change in the recorded differences in potential between the common electrode and those north and east of it, thus making an exact interpretation of the recorded potentials more difficult. Also since the original electrodes were in sand, the contact-resistance became steadily greater as the dry season advanced. At times the contact-resistance was greater than 2,000 ohms and the recorder was very sluggish.

The other system of electrodes was installed with a view to eliminating some of the deficiencies of the original set. They were placed at a uniform depth below the surface. In the hope that the natural potentials of each of the electrodes might be similar, the clay in actual contact with each electrode was transported from a situation where the resistivity of the soil was 20 ohms per cubic centimeter. The electrode R was established in the last report-year. During this year three additional electrodes were installed. Two, namely, P_x and Q_x , are north of the common point, and at respective distances of 2.0 and 3.4 km. N_x is 3.3 km. east of the common point.

The variations in the diurnal values for four of the electrodes of the original system and the four electrodes of the alternate system have been evaluated. The curves have been drawn and show general agreement with previous years. Because of the greater length of lines and more favorable electrode-environment of the new system the two independent records of diurnal variation for the eastward component are now very consistent. The new arrangement has also effected some improvement in this respect for the northward component.

Continuous records of atmospheric potential at a point 2.5 meters above the surface and 1 meter from the wall of the atmospheric-electric building were obtained by the use of a photographically recording bifilar electrometer till August 1927, and subsequent to that date by a photographically recording quadrant-electrometer. The record given by the quadrant-electrometer is well controlled by the use of the electric clock and program-machine which were installed in August 1927. The program-machine automatically lights a lamp once an hour which leaves a time-line across the electrogram. It also tests the condition of all the insulators of the system once every four hours, and photographically marks the base-line by grounding the electrometer at the necessary intervals.

A device was made and installed in November 1927 by which the base-line for the recording bifilar electrometer was obtained by grounding only the electrometer part of the system.

Tests of the insulation-resistance of the insulators were made as often as required. On occasions the leak-observations were obtained at 2^h 30^m, 5^h 30^m, 6^h, and 7^h. These observations showed that the average leak over the insulators was 0.5 per cent per minute. Under severe conditions when the relative humidity had been 100 per cent for twenty-four hours, the leak was as great as one per cent per minute. As the recorded potentials are only 0.5 per cent lower than the air-potentials for a leak of 1 per cent, the insulation-resistance of the insulators was sufficiently great.

The effective conductance from the radioactive collector to air was determined from readings of the increase in potential of the collector-system with

time after earthing, together with the resistance of the insulators deduced from the rate of leaks with the collector removed, and the measured capacity of the collecting system.

The reduction-factor to reduce the values of potential observed with the potential-gradient apparatus to volts per meter was controlled by sets of observations taken on thirteen days during the year. Additional observational criteria, necessary in order that the true value of the potential gradient at a point may be obtained, were formulated. The collector must be of such shape that the radioactive material is equally distributed about a point in a vertical plane, the activity of the collector must be such that half-value is reached in less than thirty seconds for the particular set-up that is being used, the leak-rate must be maintained at less than one per cent per minute.

A second standardizing station was established at which observations were taken in accordance with the foregoing criteria. The ground was completely cleared of all growth except very short herbage, for an area 80 meters in radius and all scrub higher than three-fourths' meter cleared from surrounding area to a distance of 150 meters from the center of the clearing. None of the electrically disturbing objects in the vicinity was closer than twenty times its height. In all, 52 sets, each consisting of 21 values at one-minute intervals, were taken at the second station. Records were simultaneously obtained with the quadrant-electrometer. The program-machine was used to light the recording lamp for three seconds every minute. The drum-speed was set for 160 mm. per hour and very accurate scalings could thus be obtained. Great care was exercised to make the individual readings in the field simultaneous with those recorded. The average of the 52 sets gives a reduction-factor of 1.13.

After the installation of the quadrant-electrometer in the atmospheric-electric building, the recording bifilar electrometer was mounted at the second standardizing station for a period of 1,800 hours. The average value of the reduction-factor from 1,150 selected hours was 1.13, which agrees with the value obtained from eye-readings. For reducing the electrograms from the recording bifilar electrometer, the calibration-records obtained during the two previous years were examined, and the relationship $V = (18.02 + 0.36t)d$ deduced, where V is the applied voltage, d is the deflection thereby produced in the fibers, and t is the temperature in degrees centigrade.

Papers on the method of making absolute potential-gradient observations and on the redetermination of the potential-gradient reduction-factor were prepared. Various memoranda relating to the performance of the several portions of the potential-gradient apparatus were prepared as required.

The atmospheric-electric apparatus for recording the conductivity of the air was in continuous operation. The preliminary mean value of the positive conductivity for the year 1927 is 1.76×10^{-4} E. S. U., and of the negative conductivity 1.51×10^{-4} E. S. U., a decrease of 7 per cent for each value over that of last year. The average value of potential gradient in volts per meter for the year 1927 was 79, which is an increase of 3 per cent over the previous year. The average air-earth current for the year 1927 was 8 per cent less than that for the previous year.

Under the heading of miscellaneous activities at the Observatory may be mentioned the following. One member of the staff attended the January 1928 meeting of the Australasian Association for the Advancement of Science which was held in Hobart, Tasmania, and presented a paper. The meteorological observations were maintained, and the barograms, anemograms

and sunshine-records were scaled and values tabulated. During the year a Federal Knight 1-ton truck fitted with 8-inch tires was received and a separate road across the 7 miles of sandy track between the Observatory and Watheroo was constructed for it. The fire-break was maintained and an adequate line for supply of water suitable for photographic work was laid to the office. A combined garage and carpenter-shop was erected and the rain-water cistern roofed.

As in former years Dr. A. D. Ross, Professor of Physics at the University of Western Australia in Perth, gave the Observatory the benefit of his advice and the stimulating influence of his suggestions.

H. F. Johnston continued in charge during the year and was capably assisted by observers J. E. I. Cairns, F. W. Wood and G. Builder. Temporary assistance was supplied by S. E. Coalstad and V. R. Brown, students in the Physics Department of the University of Western Australia.

Huancayo Magnetic Observatory, Peru—The Huancayo Observatory is in latitude $12^{\circ} 02.7$ south and longitude $75^{\circ} 20.4$ west of Greenwich at an elevation of 11,000 feet above sea-level. The magnetograph was operated continuously during the year and the absolute magnetic observations were made regularly. In addition, from the latter part of April 1927, to the first part of February 1928, magnetograph No. 5 was also recording in the variometer-room for the purpose of determining the proper adjustment of the temperature-compensation magnets on the horizontal-intensity variometer of Observatory magnetograph No. 2. During this period the room-temperature was artificially raised and lowered at times, but all other conditions were kept as uniform as possible. The mean values resulting from the weekly determinations for the year 1927 were: Declination, $7^{\circ} 50.7$ east; horizontal intensity, 0.29737 C.G.S. unit; vertical intensity, 0.00669 C.G.S. unit; and inclination, $1^{\circ} 17.3$ north. The annual changes over the year 1926 were thus 4.8 west, $+12$ gammas, $+65$ gammas, and 7.5 north, respectively. The magnetogram values have not yet been computed.

The recording potential-gradient apparatus recorded continuously during the year. Monthly standardization observations were made when the weather permitted. Comparison observations made with the recording bifilar electrometer on two hills in the vicinity of the Observatory were completed in July 1927, and a report upon data obtained was prepared by W. C. Parkinson (see p. 260).

The recording conductivity-apparatus was operated regularly during the entire year. New calibrating condensers of larger capacity were installed on September 1, 1927, and have made it possible to calibrate the instrument over the whole of its recording-range.

The earth-current recorder was in operation the greater part of the time during the year, but breakage of the eucalyptus poles which are used for carrying the lines to the electrodes has occasioned serious loss of records and a great deal of extra work for the members of the staff. The lines and the instrument were damaged by lightning, but the new arresters recently installed promise more effective protection in this regard.

The meteorological program was continued and the instruments functioned satisfactorily with only the normal adjustment and care, except for the anemograph which was somewhat damaged by rainwater from a leak in the roof. After the roof was repaired in December 1927, the instrument was overhauled, but is still recording somewhat unsatisfactorily.

The scaling and tabulation of data from the records of all the instruments have suffered delays because of the temperature-compensation work

during the first part of the year and because of reduced personnel during the second half. It will be some time in the new year before this work can be brought up to date. The monthly reports of magnetic character and storms have been prepared regularly.

Experimental work on reenforced concrete-poles for replacing the eucalyptus poles, which have not been found satisfactory because of frequent breaks, on the earth-current lines was completed. A satisfactory pole and form for its construction were developed. A satisfactory deposit of gravel for the concrete was found and one-third of the poles necessary to complete this year's program were cast. Preparations for placing the new poles are well under way.

Buildings, fences and grounds have been kept in good condition. Two sets of storage-batteries for the Delco lighting system have been installed, and two old banks have been overhauled. The quarters and the absolute building were repainted as also the living-room of the quarters. The Observatory road was kept up and improvement made in some places.

Because of the necessity of assigning Messrs. Parkinson and Torreson for *Carnegie* duty there have been many changes in personnel during the year. O. W. Torreson was observer-in-charge to February 1, 1928, and P. G. Ledig since that time. W. C. Parkinson, detailed to the Observatory on special work, left July 23, 1927, at the same time that Mr. Ledig and his family arrived. A. H. Kampe, after completing his tour of duty of two and one-half years of capable and faithful work, left the Observatory October 28, 1927. S. E. Forbush arrived October 17, 1927, and is doing excellent work. V. J. Eaton arrived June 25, thus completing once more the regular staff-membership. Señor M. T. Quintana has continued his faithful assistance with the scaling and office-records. Of the workmen engaged in the maintenance and new operations about the Observatory, B. Antesano, F. Melgar and F. Espejo deserve special notice for their trustworthiness.

Many visitors have been shown the Observatory, and its purpose and work explained. Some interest in the meteorological work of the Observatory has been shown by officials of the Peruvian Government, and they have been promised any assistance we may be able to give. The Government has also continued its general interest and the generous extension of special privileges as in past years. The United States Embassy has been continuously helpful in obtaining free entry for our supplies.

Apia Observatory, Western Samoa—Cooperation of the Department with the Apia Observatory (latitude $13^{\circ} 48'$ south, longitude $171^{\circ} 46'$ west) has been maintained, as in previous years, primarily to insure continuity of the atmospheric-electric program at this uniquely located geophysical station. It is under the general control of the Department of Scientific and Industrial Research, with an advisory board composed of New Zealand scientists. The staff is headed by Andrew Thomson as director and C. J. Westland as assistant director with one scientific assistant and six native clerks and aids. Because of ill health R. C. Hayes, scientific assistant, was replaced by K. C. Sanderson in January 1928.

The year 1927 is the twenty-fifth since the founding of the Observatory by the Imperial Society of Göttingen and the seventh year under the control of the New Zealand Government. During this period, the program has been limited mainly to an intensive investigation at Samoa of terrestrial magnetism and electricity, meteorology and seismology. The Observatory's position in the middle of the Pacific induces a uniformity in the variations which occur, not only in the climatology of the Samoan Group and their sur-

roundings but in the local conditions of terrestrial magnetism as well. The program of the routine observations of the Observatory, therefore, has been kept unaltered to discover minute secular changes. As personnel and financial limitations permitted, an effort has been made to include investigations in solar radiation and other fields in geophysics.

The measurement of the electric potential of the atmosphere at the station in the Observatory grounds and the records, with the exceptions of a few brief interruptions due to the breakdown of the insulation of the recording apparatus, have been continuous. For selected quiet days with complete records totalling 108, in which the air continued positively charged in reference to the Earth, the average potential was 130.8 volts per meter.

Three determinations were made by the Simpson method of the ratio between the electric potential at the land-station and the potential gradient per meter on a considerable area of flat ground exposed in the lagoon at low tide. The values were 1.19, 1.08 and 0.99, which give a mean value of 1.09 in exact agreement with previous years' determinations. The individual values vary considerably from one another, due probably to varying meteorological conditions in the lagoon and at the land-station.

The observing station in the shallow water off shore was reroofed in February and the atmospheric-electric installation completely overhauled. From March the records have been about 85 per cent complete, the considerable loss of records being due to the impossibility of rowing out to the house while the seas are rough. Unfortunately the failures in the insulation, due to spray and saturated air, occur most frequently during stormy weather when it is most difficult to effect immediate repair. The records of electric potential from the lagoon-station in good weather continue to show the double maxima characteristic of continental stations and are not in agreement with the finding of a single maximum per day by the *Carnegie* on the open ocean.

The magnetic program was continued with usual control of magnetograph base-lines by absolute observations at regular intervals. The mean values for the year 1927 as compiled from the magnetograms were: Declination, $10^{\circ} 29.4$ east; horizontal intensity 0.35223 C. G. S. unit. The changes over the values for 1926 were 3.3 east in declination and an increase of 7 gammas in horizontal intensity. Unfortunately considerable trouble was experienced with the vertical-intensity variometer and also with the earth inductor, and the data are largely lacking, as a result, for inclination and vertical intensity. The inductor was remade in the instrument-shop of the Department at Washington and was returned to Apia in July 1928. The usual reports regarding magnetic character-numbers have been sent regularly to the International Meteorological Commission at deBilt, and notes regarding magnetic storms have been prepared for publication.

The meteorological and seismological programs have been continued as heretofore. The important upper-air investigations were continued successfully and 89 balloons were sent up, yielding data regarding variation in height and velocity of the trade-winds; of these 31 were observed to heights greater than 10 kilometers. An interesting result from the solar-radiation data is that nearly 43 per cent of the Sun's energy fails to pass through the atmosphere over Samoa.

Several papers and reports dealing with the various activities of the Observatory were prepared and are abstracted on pages 264 to 265.

Thomson attended the Prague Assembly of the International Geodetic and Geophysical Union as a delegate from New Zealand. During July 6 to

24, 1927, he was in Washington preparing various reports for the Department on the Observatory's operations. He also prepared suggestions on the atmospheric-electric and meteorological program and instrumental improvements for the *Carnegie*. He returned in November to Samoa from Europe via the United States, leaving San Francisco October 27, 1927, after visiting the Mount Wilson Observatory. In Thomson's absence Westland was acting director.

Washington, United States—The experimental atmospheric-electric observatory on the deck of the Laboratory at Washington was continued, the routine being looked after chiefly by Sherman. Despite the disturbances resulting from the building and real-estate operations in the immediate neighborhood, the daily photographic records of potential and of the negative conductivity of the atmosphere were 95 and 85 per cent complete, respectively. While the reduction-factor determinations on eight different days in 1927 indicate a value of 1.13 as against 1.05 adopted previously, some of the subsequent determinations indicate a lower value and, therefore, pending discussion of all the data the value 1.05 as in 1926 is used (see p. 189, report for 1926-27) to get the provisional mean values of the atmospheric potential-gradient determined from the 163 daily records of "0" character for the calendar year 1927, namely, 166.7 volts per meter. The conductivity-apparatus was calibrated three times during February. The results using the new calibrating condenser were about 8 per cent greater than those obtained on the old condenser previously used. The new condenser is an enclosed type and has been adopted in order to eliminate possible insulation-leak in the old type, which also had the defect of variable capacity because of slight relative motion to one another of the inner and outer members.

In addition to numerous isolated nucleation-counts made by Wait during the year, he, Parkinson and Sherman, secured in March a third 24-hour diurnal-variation series of such counts with the Aitken instruments. This series and the two series of March 1927 show persistence of low values during the night-hours and of high values during daylight. The daily average nucleation-count for the two days in 1927 was 12,000 particles per cubic centimeter, and for the one day in 1928 it was 22,000 particles per cubic centimeter.

The control and investigations of magnetic standards in the Standardizing Magnetic Observatory have been continued. All absolute magnetic instruments for the *Carnegie* were compared with standard instruments, magnetometer No. 3 and earth inductor No. 48, including magnetometer-inductors Nos. 12 and 24, marine earth-inductor No. 7, sea dip-circle No. 189. Combined theodolite magnetometer and inductor No. 13 was compared at Washington before being sent to Africa for the cooperative field-work with the University of Cape Town (see p. 223). At Cape Town field-comparisons were made by Grindley and Sanders between theodolite magnetometer and earth inductor No. 13 with magnetometer-inductor No. 26, the instrument so long used in Africa by Sanders. Upon Sanders' return No. 26 was compared at Washington; the resulting corrections thus obtained for No. 26 at two stations so widely different in magnetic latitude are in close agreement. Redeterminations of inertia of the oscillatory system of standard magnetometer No. 3 show an excellent agreement with previous experience. Dip-circle No. 205 was also standardized for use on General Nobile's Arctic Expedition.

REDUCTION OF OBSERVATORY RECORDS

Magnetic records—Edmonds, Fleming and Ennis continued the discussion and compilations based on the completed magnetic-data tabulations for 1919 to 1926 at Watheroo Magnetic Observatory. Special forms on which to place graphs of compiled diurnal-variations were prepared and will permit direct reproduction by the planograph, thus effecting a further economy in subsequent publication of the data.

Wallis is discussing the magnetograph results of the two MacMillan expeditions of 1921 to 1922 and of 1923 to 1924 and is preparing manuscript for publication.

Electric records—Wait and Gish have made further analyses of the instrumental constants of the atmospheric-electric electrographs at the two observatories, preparatory to final revision of the hourly data as tabulated at the observatories. Fourier-analyses of some of the potential-gradient data at Watheroo were made in the discussion to determine whether insulation-leaks were affecting the recorded potentials especially during the wet seasons. The evidence seemed to indicate the possibility of such a difficulty and directions were prepared by which it is hoped any possible uncertainty in this vital matter will be eliminated. The examination and compilation of the conductivity scale-values obtained at Watheroo and Huancayo show these to be now entirely reliable and satisfactory at both observatories.

INSTRUMENT-SHOP ¹

The instrument-shop has carried out a large amount of design-work as well as construction, which has concerned magnetic, atmospheric-electric, oceanographic equipment (including physical, chemical, and biological apparatus), the complicated and extensive electric equipment of the *Carnegie* and structural changes on board required for Cruise VII. The available total of about 10,000 man-hours during the year was divided about as follows: (a) Design, construction, and installation of equipment on the *Carnegie*, this taking 60 per cent of the total time; (b) experimental work; (c) new instruments; (d) repairs and improvements to buildings, laboratory and shop; (e) stock parts for observatory, shop and field; and (f) special work.

The new equipment designed and constructed for the *Carnegie* included electric salinity-apparatus, constant-speed driving apparatus for marine earth-inductor, electrical equipment and installation with switchboard, 110-volt storage-batteries and motor-generator sets, new potential-gradient apparatus, and conductivity-apparatus for atmospheric-electric observations, three sets of Helmholtz coils for observatory use, and two ionium-collector comparison-chambers.

The experimental work included that for high-voltage research and for earth-current, atmospheric-electric and magnetic observations for the program at sea.

Repairs were made as required to the laboratory, field and *Carnegie* atmospheric-electric instruments. All sextants and magnetic and atmospheric-

¹ From the report of electrical engineer in charge of shop, C. Huff.

electric instruments were overhauled and put in first-class condition. The ion-counter was fitted with a governor-controlled constant-speed motor in place of the clock-drive for the air-turbine. The reversible gimbal-stand was fitted with a conical weight to permit driving the coil of the marine earth-inductor when mounted on it from a constant-speed motor situated in the after part of the main cabin.

Shipments of equipment and supplies were made to the Huancayo and Watheroo observatories. Schulze earth-inductor No. 2 was remade for the Apia Observatory. Equipment was made ready for the Byrd Antarctic Expedition. The design was completed and construction put under way on six gear-sets to drive recording drums at 3-hour and 25-hour rates. These sets are so designed that they may be attached to any type of clock and driven from the 12-hour shaft.

Theodolite-magnetometer No. 13 was fitted with an earth-inductor attachment and similar attachments are being fitted to theodolite-magnetometers Nos. 16 and 18. These two instruments and magnetometer-inductors Nos. 26 and 27 are being completely overhauled and refinished.

Usual attention was given maintenance of buildings, site, shop and other physical equipment. Many minor improvements to facilitate the administrative work were made in the main laboratory.

The Coast and Geodetic Survey has been supplied upon the request of Commander Heck, Chief of Division of Terrestrial Magnetism and Seismology, with non-magnetic copper castings made in the Department's foundry to overcome a suspected source of erratic behavior in the magnetic vane of the Wood-Anderson torsion-seismograph developed in the Survey's experience with that instrument. In this connection, it is interesting to note that the method devised by Huff for production of non-magnetic brass and copper castings has been sent, upon request, to an instrument-making company in Pasadena.

MISCELLANEOUS ACTIVITIES

International and national unions and commissions—Bauer was a delegate selected by the American Geophysical Union to represent the United States at the very successful Prague Assembly of the International Geodetic and Geophysical Union, September 3 to 10, 1927. He continued as Secretary and Director of the Central Bureau of the International Section of Terrestrial Magnetism and Electricity until the Assembly, when he was honored by election to the Presidency of the Section for three years 1928 to 1931. With assistance from Fleming and Harradon the manuscripts for the volume of Transactions of the Section were prepared for transmission to Professor Maurain, the newly-elected Secretary. Fleming was made a member of the International Section's Committee to act in cooperation with a similar Committee of the Geological Congress of Madrid to consider the best means of promoting research and in the methods of applying the principles of geophysics to the investigation of the Earth's crust and the minerals it contains. Bauer was named a member of the Committee on Solar Physics of the American Section of the International Astronomical Union. He continued to serve the Committee appointed by the International Research

Council for the Study of Solar and Terrestrial Relationships in formulating a scheme for international cooperative investigations of such relationships.

The Department took a large share in the deliberations of the International Section of Terrestrial Magnetism and Electricity at Prague. Communications and reports prepared by members of the staff were presented at the Assembly meetings as also detailed "Comments on the Agenda for the Prague Assembly." For abstracts of reports and papers submitted on behalf of the Department, see pp. 240 *et seq.* Bauer reports the Assembly as unusually productive and constructive. Two resolutions adopted by the Assembly bearing particularly on the work of the Department were:

"The Section (Terrestrial Magnetism and Electricity) is glad to hear that the cruises of the *Carnegie* are to be renewed. The work by the *Carnegie* in the past has been a most valuable contribution to terrestrial magnetism and electricity."

"Whereas the Apia (Samoa) Observatory is uniquely situated near the center of the largest oceanic area in the world and data in atmospheric electricity have been obtained for 24 years, the Section of Terrestrial Magnetism and Electricity expresses its high appreciation of New Zealand's present support of Apia Observatory and trusts that the investigations there in magnetism and atmospheric electricity will be continued."

In recognition of the support which the Department, through the Institution, has given scientific research in Norway, the insignia of Commander of the Second Class of the Norwegian order of St. Olav was conferred upon Bauer by the Chargé d'Affaires ad interim of Norway at Washington.

Bauer, Breit and Peters took active part as members of the American committees of the International Union of Scientific Radiotelegraphy on Atmospheric-Electric Disturbances, Variations of Radio-Wave Direction and Cooperation.

Information has been supplied the National Research Council by various men of the staff. Bauer is a member of the Division of Foreign Relations of the Council. Fleming, Gish and Mauchly continued to serve several subsidiary committees of the Division of Physical Sciences.

Active part has been taken in the formation of the American section of "Aeroarctic," the International Society for the Exploration of the Arctic by Airship, Bauer and Fleming being President and Vice-President, respectively, of the Section, the membership of which was considerably increased during the year. Bauer is a member of the Magnetic Commission of the Society charged with formulation of program for the extensive magnetic observations planned both on the airships used and at the stations on the polar ice.

As heretofore, the Department took active part in the work of the American Geophysical Union, Bauer, Fleming and Ault serving as members of the Executive Committee. Peters was made vice-president of the Section of Oceanography for one year, to June 30, 1929, and Fleming was reelected General Secretary of the Union for three years, July 1, 1928, to June 30, 1931. Ault continued as chairman of the Committee on Meetings. At the ninth annual meeting of the Union and its sections held in Washington, April 26 and 27, 1928, the Department's activities were well represented in

the several symposia held by joint meetings of sections, in particular that in the symposium and discussion on geophysical methods as applied in the study of geological structures and in the symposium and discussion on interrelations between the sea and the atmosphere and the effect of these on weather and climate. The manuscripts, illustrations, and miscellaneous matter for the transactions of the ninth annual meeting had been assembled and edited by Fleming at the end of June preparatory to publication.

Peters served as senior editor of "Journal of the Washington Academy of Sciences" through 1927 and Breit continued as one of the Board of Editors of "Physical Review." Fleming has been made associate editor with Bauer of the "Journal of Terrestrial Magnetism and Electricity."

Conferences, colloquia—Members of the Department have given increased attention during the year to reviewing and abstracting important current articles and books bearing on our fields. The weekly evening colloquium on atomic physics was actively continued throughout the year and, in addition to the helpful reviewing of recent theoretical advances and constructive criticism, was addressed by a number of eminent foreign investigators. The Department was well represented by papers and attendance at the International Radio Conference held in Washington in October 1927.

Exhibits—The Department's share in the Institution's annual exhibit in December was largely instrumental in character, the main exhibit being the earth inductor and appurtenances for magnetic observations aboard the *Carnegie*, consisting of (1) earth inductor to determine at sea the magnetic inclination; (2) amplifying unit to amplify and thus make easily measurable the small electromotive forces induced in the inductor-coil when rotated in the Earth's magnetic field; (3) gimbal-stand for mounting inductor and its driving shaft on board to overcome effects of ship's roll and pitch; (4) constant-speed apparatus for driving inductor-coil uniformly to insure same sensitivity throughout observational period. This item was supplemented by motion-pictures aboard the *Carnegie* to illustrate the conditions under which the instrument is used and to illustrate the reason for certain of the mechanical features because of the motion of the ship.

Large oil-colored transparencies showing (1) the central laboratory and office at Washington; (2) the *Carnegie*; and (3) world-chart showing progress of magnetic surveys on land and sea were prepared to be a part of the exhibit of the Institution's activities to be placed in the Carnegie Birthplace Memorial Building at Dunfermline, Scotland.

Ault, Fleming and Rooney (from January 1928) served on the Institution's Committee on Exhibits, Ault being chairman.

At the request of the Soviet Union Information Bureau, a number of publications and photographs illustrating the work of the Department were supplied for an exhibit arranged to show recent progress in geophysics, astronomy, etc., held at the Nizhni Novgorod Fair in July 1928.

Library—The number of accessions during the period July 1, 1927, to June 30, 1928, was 802, making the total number of accessioned publications 15,978. The substantial increase over the number reported for the previous year is due largely to the additional publications required in connection with the new work undertaken by the *Carnegie*. As in previous years, all articles

dealing with atmospheric electricity, polar lights, earth-currents, terrestrial magnetism and other cosmical and geophysical subjects appearing in current scientific periodicals (of which over 75 are regularly received) have been carded, classified and incorporated in the library catalogue. It has also been found possible to devote time in the course of the year to checking and reclassifying the cards in the old library index, representing chiefly publications issued prior to 1913, and to locate and enter in the new index several publications which have long been missing.

In continuing the compilation for publication of the bibliography of current publications dealing with cosmical and terrestrial magnetism and electricity, attempt was made to render the lists more useful than heretofore, by adding brief remarks and, in some cases, summaries so as to furnish readers, who do not have access to reference-libraries, an idea of the nature and scope of the respective publications. Comments from various quarters indicate that the bibliography is serving a useful purpose. Notes on current developments in our fields were prepared for publication.

A large number of articles have been translated from foreign languages in order that they might be generally available. Several of these dealt with oceanographical work of especial interest in connection with the *Carnegie's* program. Communications of the Department were translated into French for presentation at the Third General Assembly of the International Geodetic and Geophysical Union held at Prague in September 1927.

Much more extensive use of the Library has been made this year than heretofore, not only by the members of the Department but also by research workers from all parts of the country. Among the visitors, a large percentage has been of those interested in geophysical prospecting. Cordial and reciprocal relations have been continued with the Library of Congress and the other scientific libraries in Washington and have proved of mutual benefit and value in the investigational work.

A complete list of publications by members of the Department for the period 1904 to 1927 was prepared by Kolar, and was published by the Institution. The stock of reprints was properly arranged and stored so any one may be readily found for distribution as requested; this storage also provides automatic inventory and indication of those reprints no longer available.

Publications—The printing of Volume VI of the *Researches* of the Department and of reprints from it of the two sections by Fisk and Sverdrup was completed late in October. In addition to the usual distribution by the Institution to certain libraries and scientific organizations throughout the world, 250 copies of the volume were sent to other organizations interested in terrestrial magnetism and electricity. The reprints of the annual report prepared by Bauer and Fleming for the year ending June 30, 1927, from the Institution's Year Book No. 26 were received and distributed in January. Cooperation was given the Institution's Division of Publications in the preparation of three news-releases on work done. Abstracts of various articles which have been published, of papers presented to learned societies and of investigations under way are briefly summarized in the following pages.

ABSTRACTS OF PUBLICATIONS AND INVESTIGATIONS

The purpose and progress of ocean-surveys.¹ J. P. Ault. *Sci. Mon.*, vol. 26, 160-177 (February 1928); also reprinted in *The Dolphin*, Liverpool, vol. 17 (1928).

Ocean-surveys: Problems and developments.² J. P. Ault. *Jour. Wash. Acad. Sci.*, vol. 18, 109-123 (March 4, 1928).

These two papers deal with the present status of ocean-survey work and its problems and developments, particularly as regards the geophysical sciences of terrestrial magnetism and electricity, of physical, chemical and biological oceanography, and of marine meteorology, much information regarding which has been already collected, although systematic investigations are but fairly started and the vast extent of the ocean still leaves many unsolved problems. The ocean occupies so large a part of the Earth's surface that knowledge of its contents and physical conditions is of prime importance, especially so for certain problems relating to the physics of the Earth. Human life and its environment and the evolutionary processes in the living world are influenced in countless ways by the varying physical properties of the ocean.

Following a brief review of the history of the magnetic ocean-surveys beginning with that by Edmund Halley, 1698-1700, the papers discuss in detail particularly those of the Carnegie Institution of Washington on the *Galilee* and the *Carnegie*.

The author gives particular attention to those problems of ocean-surveys in which it is possible to make investigations on the non-magnetic yacht *Carnegie* in addition to the schedule in terrestrial magnetism carried out on earlier cruises. The alterations, new equipment and increased program of geophysical observations proposed for the three-years' cruise, to begin in May 1928, are given in detail.

The papers emphasize the fact that the chief advances in surveys already made have come from invention of instruments capable of revealing the variations in natural phenomena in regions hitherto inaccessible.

Surveying the seven seas with the *Carnegie*. J. P. Ault.

This illustrated lecture giving general and somewhat popularized account of the work of the non-magnetic survey on the yacht *Carnegie* was given on January 27, 1928, before the Women's Alliance and Laymen League of the Unitarian Church at Washington. It was repeated in somewhat different form February 24, 1928, at a meeting of the Patent Office Society at Washington, and April 10, 1928, at a meeting of the Men's Club of the Wesley Methodist Episcopal Church of Washington.

A three-year's cruise on the *Carnegie*. J. P. Ault.

This was the subject of a radio talk broadcast March 31, 1928, under the auspices of the National Research Council and Science Service from the station WMAL at Washington, D. C. The proposed work and route of Cruise VII of the *Carnegie* and its purposes were described.

¹ Lecture delivered at the Carnegie Institution of Washington, November 22, 1927.

² Address of the retiring President of the Philosophical Society of Washington, January 7, 1928.

Unsolved problems in terrestrial magnetism and electricity in the polar regions. Louis A. Bauer. Reprint from *Problems of Polar Research*, Amer. Geog. Soc., Spec. Pub. No. 7, 53-61 (1928).

An abstract of the matter contained in this paper is given on pages 198-199 of the annual report for 1926-27.

Preliminary report on terrestrial magnetism and electricity at the Prague Assembly, September 3 to 10, 1927. Louis A. Bauer. *Terr. Mag.*, vol. 32, 169-170 (September-December 1927).

This report summarizes briefly the 9 well-attended meetings of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union. Among matters presented from many of the 27 nations represented, especial mention is made of the proposed work of France in Indo-China and the Pacific, the progress-report of the United States Coast and Geodetic Survey, and the international aspect of the work of the Carnegie Institution of Washington. The 30 resolutions adopted as a result are summarized briefly.

Annual report of the Director of the Department of Terrestrial Magnetism. Louis A. Bauer and J. A. Fleming. *Carnegie Inst. Wash. Year Book* 26, 1926-1927, 165-213 (1927).

This report covers the operations of the Department for the year July 1, 1926, to June 30, 1927. Following the general summary the details of the various lines of work are briefly given under the following sub-headings: (a) Investigational and experimental work including terrestrial magnetism and electricity and cosmical relations, contributions of research associates, magnetism and atomic physics, experimental work in terrestrial electricity; (b) field-work and reductions including developments and improvements in magnetic instruments for field and observatory, ocean-work, land magnetic survey, observatory-work, instrument-work, and buildings; (c) miscellaneous activities; and (d) abstracts of publications and investigations. It is to be noted that the abstracts under (d) include not only brief accounts of published investigations and articles but also investigations, experiments and discussions under way during the year.

Summary of year's work, Department of Terrestrial Magnetism, Carnegie Institution of Washington. Louis A. Bauer and J. A. Fleming. *Terr. Mag.*, vol. 32, 162-168 (September-December 1927).

This article summarizes the principal activities of the Department, during the year ending June 30, 1927, in the fields of observation, investigation, discussion and publication. The field-work was limited mainly to that of one observer in Africa, to some cooperative work with other organizations, and to that being done at the observatories at Watheroo (Western Australia) and Huancayo (Peru). Investigations and discussion included the relation between solar and terrestrial phenomena, improvement of the analysis of the Earth's magnetic field, harmonic analyses of diurnal variations of the components of magnetic intensity, the variation of diurnal range of magnetic declination with magnetic latitude, and problems connecting radiotelegraphic phenomena with those of magnetism and atmospheric-electricity. Another line of investigation was that of the practicability of determining geologic formation by magnetic and electric methods, and the study of earth-currents in their relation to other allied phenomena. Laboratory investigations of methods of utilizing high potentials to elucidate some of the problems of the magnetic and electric properties of the Earth have been conducted. The development of instrumental equipment for the cruise of the *Carnegie* was

an important problem which required much attention. Volume VI of the *Researches* of the Department was issued, and contains the "Magnetic Results at Land Stations, 1921-1926" and the "Magnetic, Electric and Auroral Results of the *Maud* Expedition, 1918-1925."

Report on work done since the Madrid Assembly.¹ Louis A. Bauer and J. A. Fleming.

This report, submitted to the Third General Assembly of the International Geodetic and Geophysical Union at Prague in September 1927, summarizes the activities of the Department since the Madrid Assembly. This work has emphasized the advantage of combination of facilities for observation, experiment and investigation. The summary shows the progress made during the past three years by the Department in the elucidation and interpretation of magnetic and electric phenomena of interest, not alone to students of the Earth's magnetism and electricity, but also to the physicist, the geologist, the astronomer and the increasing circle of those interested in radiotelegraphy and telegraphic transmission.

Topics are discussed under the following headings: (a) Investigational and experimental; (b) magnetic world-survey, including land, ocean, observatory, reduction of observatory records and magnetic standards and comparisons; (c) memoranda of work done on resolutions adopted at the Madrid Assembly; and (d) publications.

With regard to work done on resolutions adopted at the Madrid Assembly, the Department, so far as possible in its program, has borne in mind the twenty-two resolutions then adopted. In the three years since the Madrid Assembly the Department made constructive contributions in accordance with sixteen of these resolutions.

Comments on the agenda for the Prague Assembly,¹ Louis A. Bauer and J. A. Fleming.

These comments include suggestions and discussions based upon the investigational land-survey, ocean-survey, observatory and laboratory work and progress of the Department upon the items of the printed agenda for the Prague meetings. The suggestions and discussions are considered under the headings: (a) Apparatus and constants; (b) magnetic and electric surveys; (c) observatory work; and (d) general proposals.

A suggestion of a connection between radio fading and small fluctuations in the Earth's magnetic field. G. Breit. *Proc. Inst. Radio Eng.*, vol. 15, 709-723 (August 1927).

This is a reprint of the paper abstracted on page 201 of last year's report with the addition of a detailed mathematical appendix, showing the mathematical derivation of the results indicated in the article.

An interpretation of Dirac's theory of the electron. G. Breit. *Proc. Nat. Acad. Sci.*, vol. 14, 553-559 (July 1928).

It is shown that Dirac's symbols, $\alpha_1, \alpha_2, \alpha_3, \alpha_4$, take place of the classical quantities $-\dot{x}/c, -\dot{y}/c, -\dot{z}/c, -(1 - \beta^2)^{1/2}$ in the Hamiltonian H given by

$$H/c + eA_0/c = mc(1 - \beta^2)^{1/2} + (\dot{x}/c)[p_x + (e/c)A_x] + (\dot{y}/c)[p_y + (e/c)A_y] + (\dot{z}/c)[p_z + (e/c)A_z]$$

It is shown, making use of Pauli's spinning-electron theory, that the above equation may be looked at as the origin of Dirac's. The new point intro-

¹ Prepared for the meetings of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union at Prague, September 1927.

duced is, therefore, the requirement that the characteristic values of the velocity-components are $\pm c$; that is, we can obtain definite information about the velocity of the electron only if it moves with the speed of light.

The propagation of Schroedinger waves in a uniform field of force. G. Breit. *Phys. Rev.*, vol. 32, 273-276 (August 1928).

The phase-difference between a Schroedinger wave refracted by a uniform field of force and the primary wave is calculated. The results are shown in a table and graphically. As the wave-length of the incident electrons increases, the phase-difference decreases, reaches a minimum and then increases again. It is suggested that the intensity of electron-reflections from crystals must vary anomalously at certain critical wave-lengths as a result of the anomalous behavior of the phase.

The production and application of high voltages in the laboratory. G. Breit and M. A. Tuve, *Nature*, vol. 121, 535-536 (April 7, 1928).

This is a report on the development of the Tesla coil as a source of high voltages. Tesla coils 39 inches long, 3 inches in diameter with ends protected by 8-inch caps give 3,000,000 volts when immersed in oil at atmospheric pressure and 5,000,000 volts when immersed in oil subjected to a pressure of 500 pounds per square inch. A million volts can be applied to an evacuated bulb, 9 inches in diameter, immersed in oil and connected to vacuum diffusion-pumps during operation. Estimates of the power available in Tesla coils for experiments on nuclear disintegration are given. The estimates indicate that the means developed are likely to prove practical and useful.

Effective heights of the Kennelly-Heaviside layer December 19, 1927, to January 16, 1928. G. Breit, M. A. Tuve and O. Dahl. *Proc. Inst. Radio Eng.*, vol. 16, 1236-1239 (September 1928).

The effective heights of the Kennelly-Heaviside layer were measured by the echo-method developed at this Department. The transmitter was operated by the United States Navy at the Naval Research Laboratory, Bellevue, Anacostia, D. C. The receiver was located 7 miles away from the transmitter, at the laboratory of the Department. In these measurements the improvements described by M. A. Tuve and O. Dahl have been used. Unambiguous results have been obtained. The average height was 130 miles during the day. In most cases a trace of a reflection corresponding to a height of 260 miles was observed. In exceptional cases corresponding to disturbed conditions and strong fading a 65-mile or 70-mile reflection was detected.

Atmospherics at Watheroo, Western Australia. J. E. I. Cairns. *Proc. Inst. Radio Eng.*, vol. 15, 985-997 (December 1927).

An abstract of this paper is given on page 203 of the annual report for 1926-27.

Conductivity of observatory collector used on potential-gradient apparatus at the Watheroo Magnetic Observatory. J. E. I. Cairns and G. Builder.

In order to determine the collector-activity and the admissible insulation-loss of the potential collector-system the capacitance of the entire system of potential-gradient apparatus No. 6 was measured, the value 82.8 cm. being obtained. With this value the insulation-resistance corresponding to various rates of leak was calculated. The collector-conductance α , in the relation set forth by Gish (see p. 254) was then determined by drawing normals to the curves derived experimentally by eye-readings on the potential-gradient

recording-drum shutter and the tangents deduced therefrom. Points at 20, 30, 40, 50, 60 and 70 seconds from the time the potential began to build up were taken on the curve and the mean ratio of the tangents for 30-second intervals was found. The individual values show a progression which is to be expected on account of the inertia of the electrometer and the departure of the collector-conductance from Ohm's law. From the mean slopes of the tangents, 2.60, the capacitance, 82.8 cm. and an insulation-resistance, 214 E.S.U. (calculated from the observed rate of leak), the value of a was found to be 2.63 E.S.U. With such a value of collector-conductance an insulation as great as 2 per cent per minute will lower the measured potential only 1 per cent.

From the mean of ten series of charging-rate observations, after some instrumental adjustments had been made, the mean value of a obtained according to this method was 3.67, which would justify the toleration of a greater insulation-leak than indicated above.

Measurement of the effective heights of the conducting layer and the disturbances of August 19, 1927. O. Dahl and L. A. Gebhard. Proc. Inst. Radio Eng., vol. 16, 290-296 (March 1928); also reprinted in Papers Gen. Assembly U. R. S. I. (October 1927), vol. 1, 3 pp. (1928).

An account is given of further improvements in the echo-method of observing effective heights of the reflecting layer. A table of values is given showing effective heights at various times of day from August 15 to 25, 1927, covering a period of general disturbance in transmission-phenomena. The table shows an increase of height after the disturbance, as compared with the days preceding it. The data obtained are compared with those furnished by Mount Wilson on disturbances in sunspots as well as with the general condition of radio reception. An unusually active spot was observed at Mount Wilson several days before August 19. If it was responsible for the disturbance its effect must have been cumulative. More systematic data are necessary to ascertain whether the rise in heights observed is characteristic of radio disturbances covering large areas.

Computation of Fourier terms. C. R. Duvall. Terr. Mag., vol. 32, 151-154 (September-December 1927).

Attention is directed to the convenience of computing Fourier terms of analyzed data by means of the Fourier coefficients. A form devised for computation by this formula in the particular case of six terms of an analysis of 24 ordinates is given and its use illustrated by an example. To have the advantage of this form in all cases, that is, to avoid necessity of passing to the phase-angle and of computing the terms by means of that very much less convenient method, formulæ for transformation of Fourier coefficients are developed. These transform the Fourier coefficients of the original analysis into those which would result from an analysis of the same number of equally spaced ordinates of the computed curve. The ordinate of the assumed zero-angle of the actual analysis *precedes* the ordinate corresponding to the zero-angle of the transformed Fourier coefficients by a given angle. A form for this transformation of Fourier coefficient is inserted on the form for computation of Fourier terms.

On the revision and correction of Fourier-analysis computations. C. C. Ennis. Terr. Mag., vol. 32, 155-162 (September-December 1927).

On account of the laborious and tedious processes involved in Fourier-analysis computations it is not only desirable but quite necessary to have

an independent control over the work, especially one that may be expeditiously applied. In the well-known Fourier formula the quantities a and b designate the Fourier coefficients and c and ϕ the amplitudes and phase-angles respectively.

The practical application of the formula to a series of n ordinates, results in the summation of products of certain combinations of the individual ordinates, t , by respective values of the sine of the variable angle for the determination of a and b . It is apparent, then, that by collecting the quantities by which each of the ordinates is multiplied, factors may be prepared by which the respective values of t are multiplied. The algebraic sum of the resulting products should equal the algebraic sum of the coefficients, a and b .

This paper contains a table of such factors for series of one to six terms and for 12 or 24 ordinates, thus affording an independent control in that the process involves the use of the values of the ordinates only.

For checking the amplitudes and phase-angles graphically a device was designed consisting of a network of horizontal and vertical lines (ordinary cross-section paper). A quadrant of a circle divided into degrees is laid down on this and at its center a graduated revolving arm of transparent material is fixed, by which, for values of a and b , the corresponding values of c and ϕ may be read off. A table of corrections is also given, whereby Fourier coefficients derived from a series of observations may be corrected on account of the "non-cyclic change" without first applying said "change" to the original ordinates.

Improved method for computing magnetic declination-observations with the marine-collimator. C. C. Ennis.

This improved method for computing the angle A between the observed celestial body and the scale of the marine-collimator, makes use of the haversine formula

$$\text{hav } A = \text{hav } \Delta - \text{hav } (h - m) + [\text{hav } \Delta - \text{hav } (h - m)]f$$

instead of the one formerly used

$$\sin^2 A/2 = \sin (s - m) \sin (s - h) \sec h \sec m$$

in which Δ is the arc between star and scale as measured by the sextant, h is the observed altitude of the star corrected for dip of horizon only, m is the altitude of scale above or below the horizon, and s is $(\Delta + h + m)/2$. The factor $f = (\sec h \sec m - 1)$ was computed and tabulated for every 30' of m from 0° to 2° and for every 10' of h from 0° to 25° , the tabular quantities being given to three significant figures so as to permit the use of Crelle's tables in conjunction with a table of natural haversines. An auxiliary table expedites the interpolation of astronomic azimuths from the usual Sun azimuth-tables.

Weighting by mean differences. H. W. Fisk. Terr. Mag., vol. 32, 163-165 (September-December 1927).

It is often desirable to give weights to mean results of groups of several determinations of a quantity based upon the order of agreement of the separate results which will be less cumbersome than the mean error from least-square adjustments and more reliable than the simple extreme range of the values in the group. The "mean difference" is here shown to serve certain cases very well. If the n values within any group are arranged in

order of magnitude, R_1 representing the extreme range or difference between the first and last of the group so arranged, R_2 , the range between the second and next to the last, and R_3, R_4, \dots, R_n , similar successive ranges, the mean difference or the mean of all the differences, found by taking each value from every larger one, is expressed by the relation

$$D_m = 2[(n-1)R_1 + (n-3)R_2 + (n-5)R_3 + \dots]/n(n-1)$$

This quantity is shown to bear a fairly consistent relation to the mean error found by the method of least-squares, and therefore is quite as useful for giving weight to group-results, while in many cases much simpler to determine.

Land magnetic observations, 1918-1926. H. W. Fisk. Reprint from Carnegie Inst. Wash. Pub. No. 175 (Vol. VI), 5-307 (1927).

This is a reprint from Volume VI of the "Researches" of the Department; an abstract is given on page 204 of the report for 1926-1927.

The magnetic anomaly in Bermuda.¹ H. W. Fisk.

This paper was presented in a general symposium and discussion of the application of geophysical methods to the determination of geological structures and summarizes briefly the author's observations and studies of the magnetic anomaly in Bermuda, in which he showed that the instruments devised by the Department could be used for rapid detailed surveys of disturbed areas, and from the analysis of the resulting observations, that there were revealed two distinct sources of disturbance, one lying in the soil at the surface and the second arising from the deep underlying rocks upon which the island rests.

An attempt to adapt variations of magnetic elements from observatory-records to field-observations. H. W. Fisk.

Observations of magnetic declination, inclination and horizontal intensity are made at field-stations at such hours and on such days as the exigencies of the survey may dictate. The determination of secular variation demands that the mean change in the value of each element for a year be derived. But the momentary value of the element may differ from the mean value for that date and place by an amount as great as, and often many times greater than, the mean change for an entire year. How to correct these field-observations to a mean value for the day and station is a problem for which no satisfactory solution has been proposed. The establishment of temporary variation-observatories is the obvious solution but is impracticable by reason of the cost. The use of the results of the existing observatories is the next best solution, but for much of the Earth's surface, the observatories are too remote for direct use. A variety of differences must be considered to make the transfer from observatory to field-station: namely, (a) the difference of phase with longitude, (b) the difference of amplitude with magnetic latitude, and (c) differences due to perturbations. Were it not for class (c), the differences (a) and (b) might be eliminated by the comparatively simple device of making diurnal-variation observations in the field at frequent intervals. This method has been tried out in field-practice by the Department for several years with valuable results.

An effort to make practical application of the observations was made in the discussion of the declination-observations in the survey of Madagascar

¹ Presented before the Pick and Hammer Club, Washington, November 19, 1927.

from October 1920 to July 1921. The records of the Royal Alfred Observatory at Mauritius for the period were available and were compared with the field diurnal-variation observations made at twelve different stations on the island. The observatory is at nearly the same latitude as the middle of Madagascar and about 800 miles to the east; the length of the island is approximately 1,000 miles from north to south. The position of the observatory for comparison with this field therefore is much more favorable than is usually the case for stations outside of Europe or the United States. The similarity of the curves taken simultaneously from observatory and field-observations was usually close, but there were differences both of phase and amplitude which could not be assigned to the ordinary changes because of different latitude or longitude. These represented the effects of perturbations which produced different effects at the two stations compared. In order to trace these perturbation-effects if possible, the records for the twelve days were examined for a number of observatories for which the results were available. These included the five United States Coast and Geodetic Survey observatories, and those at Samoa, Christchurch and Watheroo. As a result of this examination, perturbations were recognized which (a) produce high or low means affecting successive stations in varying degrees, (b) produce simultaneous effects at widely separated stations which may take the same or opposite directions, (c) move progressively but at a rate different from the change in local time, and (d) move forward approximately as local time but rise during their progress to a maximum and disappear later in the forward movement. There are also differences that seem to be characteristic of the region in which the field-station is located.

Very important alterations may take place in the character of the daily curve within so short a distance as 700 to 800 miles, so that diurnal-variation corrections derived from an observatory may not be entirely satisfactory even at this distance. After modifying the observatory-curves as seemed to be indicated by the results of the comparison with the curves for field-stations, and after taking into account the difference of local time, the observations at the 84 localities in Madagascar were corrected to the mean value by their application. Usually two observations of declination were made at each place, separated by about one and one-quarter hours. In general these two values were in better agreement after the application of the correction than before; it should be noted, however, that the observations were more often made near the time of the elongation of the daily curve where the error in the time of maximum or minimum would be more likely to produce a difference in the wrong direction, than during the time of rapid change, where the sign of the difference between the first and second observation would be right but its magnitude in error. For the same reason the corrections as applied will usually have the proper sign and the corrected values of declination will therefore be an improvement on the observed values.

Magnetic survey of lower Potomac during April to May 1928. H. W. Fisk.

The location chosen for the swings of the *Carnegie* at the beginning of Cruise VII was in the lower Potomac, about 100 miles south of Washington. In this region it appeared probable that a better control of the inequalities in magnetic distribution, known to exist generally in those portions of Maryland and Virginia, could be obtained than in the Chesapeake Bay where the distance between shores was greater. During the two weeks

preceding the arrival of the *Carnegie* a party of three observers made complete observations at 26 stations as close to the shore as practicable along both sides of the river and along lines roughly paralleling the shore some distance inland. These lay within a quadrangle about 30 miles square, with the swing-position of the *Carnegie* near the center. A similar survey along the shores of Chesapeake Bay had been made at the departure of the vessel on the previous cruise in 1919 and seven stations of that survey within the limits of the quadrangle were included in the first adjustment. To reduce all the field-observations to a common basis, the simultaneous results recorded on the Cheltenham magnetograms were scaled and the difference of each individual result from the mean of all the Cheltenham scalings was applied to the corresponding field-value. The assumption that such differences would apply unaltered over the relatively short distance from observatory to field had been fully confirmed by comparing the diurnal-variation observations in the field with the magnetograms. The position of each field-station having been accurately determined from detailed maps of the U. S. Geological Survey, it was possible, by least-square adjustments, to derive a reliable rate of change of each element with change of geographic coordinates, and thus to interpolate with reasonable assurance the normal value to be assigned to positions in the river where observations with the vessel's instruments were made. The first adjustment using all 33 stations showed such extensive regions of disturbance and such large consequent residuals, that a second trial was made using only those stations near the shore as near as possible to the ship's position. The results were thus greatly improved, and after grouping the observations so that a reasonably uniform distribution of results within the smaller area was secured, a third and final adjustment was made. The graph of residuals for this adjustment, because of some consistency of arrangement, suggested abnormalities that could be outlined on the land, but not under the river. Considering the depth of the river and therefore the distance of any possible source of disturbance from the magnetic instruments, the residuals, which were never greater than the order of accuracy to be expected from ship's instruments under ordinary conditions, might logically be assumed to vanish at the position of the ship's observations. In order, however, to recognize the existence of these inequalities, a rough method of distributing their influence in proportion to their distances from the water-stations was adopted, but the resulting changes were immaterial.

During the ship's standardizing observations, simultaneous observations at Kitts Point near the swing-position furnished an additional control on the normal values to be assigned there in tests for possible ship's deviation-coefficients.

In the experiments on a method of using the earth inductor for measuring horizontal intensity at sea, observations were made also at this shore-station simultaneously with observations with that instrument aboard. The station at Kitts Point was selected as a base for the magnetic work, largely on account of its adaptability as a station for standardizing the potential-gradient apparatus—being flat and of uniform geological structure so far as surface appearances indicated and also free from undesirable structures or vegetation.

Isomagnetic charts of northwestern Peru. H. W. Fisk and C. C. Ennis.

In order to comply with a request for charts showing the distribution of the horizontal and vertical intensity of the Earth's magnetic field in the

general region of northwestern Peru, existing charts were carefully compared with the most recent data, and none was found to be adequate. New charts were therefore prepared, showing the distribution of these two elements for the epoch 1926.0, though time did not suffice for employing methods of reduction of utmost refinement. The chief difficulties encountered were those arising from the unusually large and rapidly changing rate of secular variation of the inclination, the large range of diurnal variation of horizontal intensity and the existence of local disturbance in the mountainous regions of southern Ecuador. Although the charts were limited to the region between 3° and 10° south latitude and west of 77° west longitude, observations at about 80 stations extending from Bogota to Lima and eastward to Iquitos were included in the discussion. The derivation of an equation representing the lines of equal horizontal intensity over a larger area was not practicable because of the sharp curvature of those lines over northern Colombia and Central America. For the more restricted area, however, a straight-line equation was found to fit the observations very satisfactorily. The equations found were

$$\begin{aligned} H &= 0.3145 - 0.00131 \Delta\phi - 0.00129 \Delta\lambda \\ Z &= 0.0654 + 0.01102 \Delta\phi + 0.00235 \Delta\lambda \end{aligned}$$

In these equations $\Delta\phi$ and $\Delta\lambda$ are changes in latitude and longitude in degrees considered positive toward north and east respectively, measured from the point 5° south latitude and 81° west longitude as origin, and H and Z are expressed in fourth decimal C. G. S. unit.

The magnetic and electric observations of the *Maud Expedition* during 1918 to 1925. H. W. Fisk and J. A. Fleming. Terr. Mag., vol. 33, 37-43 (March 1928).

The full report of the magnetic and electric work of the *Maud Expedition* has been published in Volume VI of the Researches of the Department and this article gives in a condensed form some of the principal results developed in the accompanying discussion by Dr. Sverdrup, the scientific leader of the Expedition and the author of the report. The work of the Expedition falls into two parts, from July 1918 to the summer of 1921, after three winters in northern Siberia under the personal command of Captain Amundsen, and from 1922 to 1925 under the command of Captain Wisting, on this occasion drifting with the arctic ice. At Cape Chelyuskin during 1918 to 1919 and at Four Pillar Island during 1924 to 1925 conditions permitted photographic registrations of magnetic declinations and these results are discussed. The striking difference between the mean curves of daily variation at these two stations is shown by a figure which compares also results at polar stations of other expeditions. The mean absolute daily range of declination at Four Pillar Island for the months December to May was $0^{\circ} 37.5$, while at Cape Chelyuskin it was $5^{\circ} 35.5$. Some secular-variation results are given by comparison with results obtained in 1822, 1878 and 1893. One unusual result was the detection of two regions of local disturbance in the Arctic Ocean in 76° north latitude, one at about 155° and the other between 163° and 168° east longitude.

During the second part of the Expedition, 1922 to 1925, systematic observations of atmospheric-electric potential gradient were made and the results confirm the conclusion reached from consideration of the *Carnegie* observations, that this element reaches a maximum or minimum simultaneously over the Earth, and is not dependent on local time. Observations of the aurora took an important place in the work of the *Maud* party, and valuable results

were obtained. The types of auroral appearances were recorded under five broad classes, namely, glow, arch, curtain, streamer and corona, and observations were made showing date, local mean time, form, intensity on a scale of 1 to 4, azimuth and altitude. The relation of auroral character-number to magnetic character-number was confirmed.

Latest annual values of the magnetic elements at observatories. J. A. Fleming. *Terr. Mag.*, vol. 33, 95-99 (June 1928).

International Geodetic and Geophysical Union (actions pertaining to standards, standard instruments, and nomenclature). J. A. Fleming. *Standards Year Book 1928*, Washington, D. C. Dep. Comm., Bur. Stan. Misc. Pub. No. 83, 20-24 (1928).

This note briefly summarizes actions pertaining to standards, standard instruments and nomenclature taken by the International Geodetic and Geophysical Union at its Third General Assembly held in Prague in September 1927. The fields covered include geodesy, seismology, meteorology, terrestrial magnetism and electricity, and oceanography, the sections of volcanology and scientific hydrology not having passed any resolutions that might concern standards, standard instruments or terminology.

Transactions of the American Geophysical Union, eighth annual meeting. April 28, 29, 1927, Washington, D. C. J. A. Fleming (Editor). *Bull. Nat. Research Council*, No. 61, 296 pp. (July 1927).

Program of scientific work on Cruise VII of the *Carnegie*, 1928-1931. J. A. Fleming and J. P. Ault. *Terr. Mag.*, vol. 33, 1-10 (March 1928).

The seventh cruise of the non-magnetic yacht *Carnegie*. J. A. Fleming. *Science*, vol. 67, 478-479 (May 11, 1928).

Cruise VII of the *Carnegie*, 1928-1931. J. A. Fleming and J. P. Ault. *Nature*, vol. 121, 871-873 (June 2, 1928).

Program of scientific work on Cruise VII of the *Carnegie*, 1928-1931.¹ J. A. Fleming and J. P. Ault.

These communications give in detail the program and plans for the world-wide cruise of the *Carnegie* begun May 1, 1928. This, the seventh cruise of the vessel to continue to September 1931 will add over 110,000 miles to the present total of nearly 290,000 miles traversed in all oceans during cruises I to VI (1909-1921). The program of scientific work to be undertaken includes, in addition to investigations in terrestrial magnetism and atmospheric electricity in continuation of those previously undertaken, some work in physical, biological and chemical oceanography, and an enlarged schedule in marine meteorology.

The practical and theoretical value of the magnetic work already done on the *Carnegie* is attested by the principal hydrographic establishments of the world and by individual investigators. The value of the data obtained will now be enhanced by additional observations to determine the secular-variation (or progressive) changes of the Earth's magnetism. While this information is needed for practical navigation, future magnetic work at sea is far more necessary for the advancement of theoretical studies. Accurate and extended data are required for a number of epochs to advance the investigation of causes producing and laws governing these changes. Not only will observations be repeated in localities previously surveyed by the *Galilee* and *Carnegie*, but additional information will be obtained regarding

¹Presented for the authors by H. U. Sverdrup, May 26, 1928, before the Oceanographic Conference held in Berlin during the Centenary Celebration of the Gesellschaft für Erdkunde zu Berlin.

the distribution of the magnetic elements in some large areas not yet surveyed.

Data for further investigations on the origin and maintenance of the Earth's electric charge of relation to the Earth's magnetic condition will be obtained throughout the cruise. Photographic methods have been provided to continuously record variations in some of the atmospheric-electric elements. These it is expected, in addition to confirming fundamental phenomena previously disclosed by work of the *Carnegie*, will add materially to the knowledge of distribution and variations of the atmospheric-electric elements.

In addition to the magnetic and electric work it is possible because of rebuilding of the vessel and increase in scientific personnel to carry on an extensive program in oceanography. In physical oceanography it is planned to investigate the topography and configuration of the ocean-depths by the sonic depth-finder; to study the causes of movements of vast bodies of water relatively to one another—the dynamics of the sea—by measuring differences in temperature and salinity over the surface and at various levels down to a maximum of about 6,200 meters; to secure information regarding the nature and origin of inorganic marine deposits by sampling the bottom muds and sediments; and to increase our knowledge of the physical interchange between the surface of the ocean and the air above it by measuring the temperatures and humidity lapse-rates of the air in the first 35 meters above the surface, and by observing the variations in the amount of solar radiation received at the ocean surface.

The proposed biological and chemical program planned is to be directed chiefly toward the study of the chemical and physical environment of the marine plankton in the upper 500-meter stratum. An intensive study is planned in addition into some of the physiological conditions of existence of one of the planktonic groups (probably the Schizopods) in which field-observations will be linked with laboratory experiments.

The chemical field-work is to be concerned largely with the analysis of water-samples for phosphate, silicate, hydrogen-ion concentration and, occasionally, nitrate, oxygen, alkalinity and carbon dioxide. Water-samples will be collected from the surface down to 6,000 meters.

The physiological studies must be made chiefly while the vessel is in port. It is hoped to conduct determinations of the rates of metabolism, growth and reproduction, and the variation of these vital processes with temperature and hydrogen-ion concentration on some selected group. While the expedition is in tropical waters a study of the flotation-organs of planktonic organisms and of their relation to temperature and viscosity of the water is planned.

The papers describe in detail the structural alterations necessary to the vessel because of the increased program. Briefly detailed descriptions of the instrumental appliances and equipment are also included.

The details of the tentative schedule for the cruise are followed by references to the generous cooperation and expert advice on all sides from interested governmental and private organizations and individuals both in America and Europe.

On "non-cyclic" corrections at the Watheroo Observatory.¹ J. A. Fleming and H. M. W. Edmonds.

The so-called non-cyclic changes in magnetic declination, horizontal

¹ Report prepared for the meetings of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union at Prague, September 1927.

intensity and vertical intensity as obtained at the Watheroo Magnetic Observatory during the years 1919 to 1924 for the means of five differences and of ten differences for the same hours on successive days have been tabulated. The values of differences obtained for the five days (international quiet, referred to Greenwich mean time) and for the ten days (selected quiet, referred to local zonal time) differ very frequently in sign for declination and at times for horizontal intensity and vertical intensity. They also differ considerably in value. They differ enormously from values which would be obtained considering such changes as a possible reflection largely of secular changes not only in magnitude but also in sign for horizontal intensity and vertical intensity. Moreover, decidedly different values may be obtained depending upon the particular hours selected.

As a test of any question of non-uniformity of data as regards working from groups all based on Greenwich mean time, the data for vertical intensity at Watheroo for the year 1919 were tabulated to show the hourly values before and after the beginning of the Greenwich-mean-time day for each of the five international quiet days and for each of the five next quiet days as indicated in the International List of character of days. Comparison of the results for individual days in this tabulation shows great differences in non-cyclic-change values according to the particular days used and the number of days used.

Test-compilations were made also for groups of successive quiet days in 1921, 1922 and 1923 in horizontal intensity according to the international selection. The non-cyclic differences were determined for the successive Greenwich hours by using the means of hourly values in each group for the first three and for the last three days. Comparison of these results again shows great differences in daily non-cyclic-change values according to the hour used from which to determine the change.

Thus the magnitude of any non-cyclic correction apparently will depend upon the particular selection of hours for beginning and ending for any given set of days. It, therefore, seems that publications of observatory results should give values without correction for non-cyclic changes. There will probably always be a question as to the method of applying any such change, and at any future time this method may be the more readily modified if the original data are supplied. It is further to be noted that the number of days involved in determining such changes is usually too small to prevent a moderate irregularity in one day from influencing the correction as determined. In any case, the uncertainties of scaling, of temperature, of temperature-correction and of scale-value will frequently approach a magnitude comparable with such non-cyclic corrections. It is almost invariably true that one or more of the five best selected days show some feature which in itself is frequently sufficient to vitiate any deduction regarding a non-cyclic correction. This uncertainty is naturally increased for observatories in the higher latitudes where the definition of quiet, that is, normal, days is even more difficult.

Summary of magnetic-survey work by the Carnegie Institution of Washington, 1905-1926. J. A. Fleming and H. W. Fisk. *Terr. Mag.*, vol. 33, 27-36 (March 1928).

This is a condensed summary of the operations of the Department in which the distribution of its magnetic and electric stations over the Earth is set forth in five tables and three full-page figures. The distribution of the total of 5,685 station-occupations among the twelve geographical divisions of the Earth's surface is tabulated, arranged according to epochs

corresponding to the periods covered by the four volumes of published "Researches." Of these station-occupations, 1,435 have been reoccupations in 561 repeat-localities, and 720 have been auxiliary stations established in the vicinity of other stations to investigate local disturbance or to avoid the effects of local development. The distribution of the repeat-localities among the various countries and island groups is also tabulated and illustrated by an equal-area map of the world. The location of each magnetic station and the track of each cruise of the *Carnegie* and *Galilee* through 1926 are shown on another world map. The two vessels have secured values of the declination at 3,316 stations in the three oceans, and of the other two elements at 2,147 stations. On these cruises, besides magnetic work, one or more of the atmospheric-electric elements was observed at 955 stations, and diurnal-variation series of more than four hours' duration were obtained at 96 stations. These stations are summarized in a table and their locations given on a full-page Mercator chart.

The article also deals in a general way with the development of the instruments used in the surveys on land and sea, and with methods of maintaining constant magnetic standards of reference. The more recent practice of securing specimen curves of the daily changes in the magnetic elements at field-stations is also mentioned, and the potential value of such work is emphasized.

Preliminary notes on intensity-constants of C. I. W. magnetometers. J. A. Fleming and H. W. Fisk.

The computation of horizontal intensity from observations with a magnetometer depends upon two so-called constants, the moment of inertia of the oscillating magnet and its suspension, and the distribution-coefficient for the pair of magnets used in deflections. Change in the correction on any adopted magnetic standards of a given instrument is dependent upon changes in these constants. This note points out that for the magnetometers of the Department the change in the correction to standard during any interval is almost exactly that which would have been produced by the change in the moment of inertia that was actually determined by observations at the beginning and end of that interval. From this it follows that no appreciable part of the change in the correction was due to an alteration in the distribution-coefficients, which are thus shown to be sensibly constant. Thus the necessity of frequent control of the moment of inertia of the oscillating magnet is also emphasized. Since the distribution-coefficients, P and Q or the equivalent of P' , are derived from a consideration of the relation between deflection-angles at two or three distances, and since these constants are very sensitive to slight variations in this relationship, it is essential that the deflection-distance and temperature of deflection-bar and of magnet be accurately controlled. In the Department's instruments the constancy of the deflection-distance has been satisfactorily maintained by the design of the deflection-bar and the magnet-carriage, a tapered pin in the latter being fitted snugly into a hole or slot similarly tapered in the former. The control of the second condition, the temperature of the bar and the magnet, is not so satisfactory, since there is an unavoidable lag between the effect of a change in temperature on the thermometer and that on the magnet. This produces apparent changes in the distribution-coefficients, P and Q , which are not real.

All observations whether in the field or at fixed stations are made at three distances by observers of the Department and in this way a large amount

of data for discussion of P and Q is available for all the instruments of the Department. While P and Q are both computed from these observations, their sensitivity to uncontrolled conditions such as temperature and slight errors in observation or adjustment causes individual determinations to vary considerably. Since, however, the dimensions of the magnets are so related that the second coefficient should vanish, theoretically, it has been found that an equivalent single coefficient P' , on the assumption that Q does so vanish, is much less subject to these accidental variations and is sufficiently accurate to meet all ordinary requirements of field and observatory.

This constancy of P' is illustrated by a table showing the mean value of that coefficient for C.I.W. standard magnetometer No. 3 for each year since the beginning of its use in 1907 through June 1926, from a total of 1,234 sets of deflections at three distances. If we omit the years 1907 to 1910 during which there was some variation in practice, the annual means of the value of P' varied between 13.34 and 13.54 as extremes, with a weighted mean value of 13.381. Had this mean value of P' been used instead of the adopted values of P and Q , the mean annual value of H would in no year have been altered more than $0.00008H$ if we again except the years 1907 to 1910. A slight progressive change in the moment of inertia of the oscillating magnet of this standard instrument is shown by the formula determined from frequent determinations of inertia. This shows a decrease linear with date amounting to only 0.000005 per year in the value of the logarithm of the inertia-constant. The conclusion is that for magnets of high-grade homogeneous steel, properly treated when magnetized, and assuming ordinary care during use, the distribution-coefficients are sensibly constant over long periods. Apparent deviations from constancy indicated at times in compilations are usually traceable to blunders, to uncertainties in actual temperature-conditions during observations, or to changes in the moment of inertia.

On the reliability of earth-current potential measurements.¹ O. H. Gish.

An estimate of the reliability or significance of the values recorded from earth-current lines is possible if for each component at a given station two, or preferably more, independent registrations are obtained. This has, however, seldom been done, with the result that when using earth-current data the investigator is in much the same position as the navigator on a ship which has but one chronometer.

At the Watheroo Magnetic Observatory three independent registrations of each component are obtained. This arrangement has proven very helpful in distinguishing the features of extremely local character from those of general interest, and has made possible the identification and elimination of some extraneous effects. The evidence furnished by three years of record at this Observatory strongly indicate:

- (1) That no conclusions can be drawn regarding the existence of a constant earth-current component. The greater part of the measured value is an effect of extremely local character, most likely an electrochemical contact e.m.f.

- (2) That the annual variation in the recorded values is chiefly an effect of extremely local character, apparently caused more or less directly by changes in the moisture-content of the soil near the electrodes.

¹Report prepared for the meetings of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union at Prague, September 1927.

(3) That the diurnal variation derived from the hourly means for a month is, with proper installation of electrodes, very reliable. However, without at least a duplicate system of electrodes, certain extraneous effects having a diurnal period may creep in undetected.

(4) That disturbances of period of a few hours or less can be determined with least difficulty.

It is the writer's view that these conclusions apply to earth-current data in general, and it is hoped that the implications of conclusions (1) and (2) will be given more attention in the future, especially by authors of general treatises on the subject of earth-currents.

On the relatively large values of earth-current potential recorded at the Ebro Observatory.¹ O. H. Gish.

While making a resistivity-survey at the Ebro Observatory during September to November 1926, it was suggested by the Reverend I. Piug, S.J., that the writer, if possible, make an independent determination of the constants required in evaluating the earth-current registrations obtained there. By using the portable potentiometer of the Department's earth-resistivity equipment it was possible to make direct measurement of the potential between the line-terminals which are normally connected to the recording galvanometers. These values were then compared with those obtained from the photographic records by taking the mean of the ordinates just before and just after the short interruption caused by the potentiometer-measurement. The greatest difference in the two sets of values thus obtained was about 5 per cent, in the relatively small west-east component, which can be caused in large part by the always noticeable variations in the potentials to be measured. Direct comparisons of the potentiometer with secondary standards were made beforehand at Watheroo by W. J. Rooney and afterward at Washington, as well as an indirect comparison at the Ebro Observatory with two Weston milliammeters of model No. 1 in series with a standard resistance which furnished an *ir* drop suitable for the potentiometer. On the basis of these comparisons the largest allowable error in the potentiometer-readings is 0.2 millivolt, or less than 2 per cent of the smallest reading. In view of these results the large amplitude of the semi-diurnal variation of earth-potentials at the Ebro Observatory must be considered one of the set of facts which a theory of earth-currents, to be acceptable, must harmonize.

Depths of ground-water and other subsurface features indicated by earth-resistivity surveys.² O. H. Gish. Terr. Mag., vol 33, 140-141 (1928).

With the instrumental improvements embodied in the equipment now used for resistivity-surveys by the Department, disturbing effects from insulation-leaks, from contact-potentials at the potential electrodes and from transients are made negligible. By obviating these effects, especially the last, all the advantages of a direct-current method have been realized without the usual disadvantages, and it has been possible to obtain very consistent measurements of the effective resistivity in given regions.

¹ Report prepared for the meetings of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union at Prague, September 1927.

² Presented at the joint meeting of the Sections of Terrestrial Magnetism and Electricity, of Seismology and of Geodesy of the American Geophysical Union, Washington, April 26, 1928.

Although these surveys were made primarily to ascertain the resistivity of undisturbed earth for its bearing in the study of earth-currents, yet the method has shown itself capable of use for ascertaining the ground-water level in places and the extent of certain types of overburden down to depths of nearly 300 feet. Indications which may be interpreted as a change in geological structure at depths as great as 1,200 feet have been obtained, but for these there is as yet no independent evidence available.

Requirements as to collector-activity and insulation-resistance in measurements of air-potentials. O. H. Gish.

By equating the sum of the charging current and leakage current to the conduction current at the collector and solving the resulting differential equation, the relation $v/V = [ar/(1 + ar)][1 - e^{-[(1+ar)/Cr]t}]$ is obtained. In this v is the observed potential, t seconds after earthing the collector-system, V is the air-potential assumed constant, a is the collector-conductance, r the insulation-resistance, and C the capacitance of the collector-system. The assumption here made, namely that the conductance is ohmic in character, is only approximate. If C is known, r can be determined from observations of the rate of decrease of potential of the system with the collector removed.

From observations of v at a series of equal intervals after earthing the collector-system, a may be advantageously obtained from the relation

$$a = (C/n) \log_e (\Delta_i / \Delta_{i+1}) - 1/r$$

where $\Delta_i = v_i - v_{i+nh}$, n is the number of seconds in each of the equal time-intervals between observations of v , and h is the number of such time-intervals between v_i and v_{i+nh} . The number of time-intervals is so selected as to make the values of Δ as large as possible and yet use all the data but once. The value of Δ_i / Δ_{i+1} should be constant but variations arise from changes in V and from departures of the collector-conductance from Ohm's law. Observations made at Watheroo by Cairns and Builder (see p. 241) yield values of this ratio or of a , which increase to a maximum as the series progresses, then decrease toward the end of the series. The former may be attributed to saturation-conditions at the collector and the latter would result if the collected current varies as the square of the potential difference between the nearby air and the collector. Such conclusions, however, may not be justified on account of the variations in V , which may not be completely eliminated in the means of the ten series of observations. Even with the minimum value obtained in these calculations losses over insulators as great as 1 per cent per minute would lower the equilibrium value of v , namely $v \doteq V (1 - 1/ar)$, by about 1 per cent.

An induction-method of measuring earth-currents. O. H. Gish.

During the summer of 1927 tests were made, in the laboratory, of a method in which a ring of permalloy, wound with a considerable number of turns of magnet-wire and so placed as to make a linkage with the unknown current, was used. By rotating this ring about an axis in its plane and by other methods of varying the linkage with the unknown current, a current-pulse is induced in the winding. From the measurement of this and the constants of the ring the unknown current can be calculated. These tests indicate that it will be possible, with a ring of manageable size and using a sensitive Thomson-type galvanometer, to detect in this manner earth-currents of magnitudes as small as are deduced from earth-potential and earth-resistivity measurements. The method is admittedly difficult and not suitable for recording but should serve as a check on determinations

made by present methods and to ascertain whether any considerable constant component of earth-currents exists.

Variations in penetrating radiation over the oceans and at the top of the Washington Monument. O. H. Gish and C. L. Frederick.

A study of penetrating-radiation measurements obtained on the *Carnegie* during cruises IV and VI and of ten diurnal-variation series obtained by Frederick at the top of the Washington Monument, during January to March 1928, shows noticeable irregular variations. In the case of the observations on the Monument a definite correlation between some of these and meteorological conditions is found. However, for the data obtained at sea on the *Carnegie* a similar correlation is not evident and in view of the absence over the oceans of appreciable radioactive material the cause of these variations is a matter of considerable interest. Tests were made to ascertain to what extent they might be attributed to instrumental sources with the result that such a cause seems inadequate in most cases. These data were also examined for a possible variation, proceeding according to sidereal time. The observations at the top of the Washington Monument, on account of the very large irregular variations observed there, perhaps can not be taken to indicate definitely such a variation. The data from the *Carnegie*, however, obtained in the belt between latitude 30° north to 30° south bear out the findings of Kolhörster, Büttner and others. The data north of 30° north latitude are inadequate for this purpose, but those south of 30° south latitude, however, show a variation of a definite character with maxima at 6^h or 7^h and 21^h or 22^h sidereal time, but no maximum at approximately 17^h as was found by us for the *Carnegie* observations in central latitudes and by Kolhörster and others from observations in Europe. The number of observations available in this belt is greater than for any other, which probably accounts for the more definite indication of variations of this character.

On methods of calibrating the Department Terrestrial Magnetism steady-deflection air-conductivity recorder and regarding selection of suitable capacitance and resistance. O. H. Gish and K. L. Sherman.

In the steady deflection-method for measuring air-conductivity, the current collected at the central electrode in the air-flow tube is carried through a radioactive cell whose resistance is of the order of one electrostatic unit. The potential drop across this resistor is recorded by means of a quadrant-electrometer. With this arrangement, as regularly used at the Department's observatories, a deflection of a millimeter at a distance of a meter is produced by a current of about 3×10^{-14} amperes. Calibration in terms of current is accomplished by substituting a known current for the unknown. This is produced by a potential, varying at a steady and known rate, applied across the radioactive cell, and a fixed condenser of known capacitance placed in series. An alternative method of supplying this current is to use a constant potential with a condenser whose capacitance may be varied at a known and steady rate. The device developed for applying the capacitance-method is much simpler and requires less attention than the equipment used with the variable-potential method. The variable condenser in its preliminary form is cylindrical in type, the outer cylinder being 50 cm. long and 5.5 cm. inner diameter. A central electrode 5 mm. diameter and 25 cm. long is supported at one end of the assembly by an amber insulator which is supplied with a guard-ring. An inner concentric cylinder, 2.4 cm. diameter and 25 cm. long, makes sliding contact with the outer cylinder. For each centimeter displacement of the sliding cylinder along its axis a

uniform change in capacitance of about 0.1 cm. results, provided its open ends do not approach very near the ends of the central rod. The central rod is connected with one terminal of the radioactive cell, the other terminal being earthed and connected with the guard-ring. The constant potential is applied between the outer cylinder and earth. Using the change of capacitance calculated from the dimensions of this condenser, comparisons of the two methods showed no difference greater than the experimental error, thus confirming constants previously determined. The capacitance of the system containing this condenser should be as small as possible since, with the high resistance of the radioactive cell, the time required for the current to reach its full value may be excessive. For this reason the maximum capacitance of such a condenser, and hence its total change, should be made relatively small. Although greater sensitivity could be obtained with this method of measuring small currents by increasing the resistance of the radioactive cell, the increased period of the system soon becomes an obstacle, especially as regards calibration. This is brought out by the fact that with the systems used for recording air-conductivity at the observatories of the Carnegie Institution of Washington, the half-period is about one minute, hence the time required for each calibration-point is from 5 to 6 minutes. By reducing the resistance of the radioactive cell, improvement would be effected in the features just mentioned but, with the greater sensitivity required in the electrometer, such troubles as variation in contact-potentials become emphasized, especially during calibration with the variable-potential method.

On earth-current observations at Watheroo Magnetic Observatory, 1924-1927. O. H. Gish and W. J. Rooney. *Terr. Mag.*, vol. 33, 79-89 (June 1928).

The earth-current measuring system at Watheroo Magnetic Observatory provides for a number of independent records of both components of potential gradient, a feature which has proven helpful in detecting and locating the source of disturbing effects. The results obtained during the four-year period 1924 to 1927 are discussed. The diurnal-variation curve of the northward component has a mean range of 1.14 millivolts per kilometer with maxima at 17^h.5 and 12^h.5 and minima at 8^h and 17^h.5 (120th meridian mean time). The records resemble those obtained in the northern hemisphere at Berlin and Ebro, except that the curve is inverted and smaller in amplitude. The reversal in the direction of current-flow points to a symmetrical distribution of earth-currents with reference to the equator. The small amplitudes can be explained on the basis of the unusually high conductivity of the region about Watheroo. No regular change was observed in the mean diurnal-variation for individual years. The range of the seasonal variation-curve varies with season from 0.71 millivolt per kilometer in June (midwinter) to 2.06 millivolts per kilometer in October (late spring), and the morning minimum and midday maximum shift forward with increasing height of sun. The amplitudes of the three principal harmonics vary with season in a similar manner, indicating a single predominating course for seasonal variation in the normal activity. The eastward component is extremely small at Watheroo. The diurnal-variation curve has, in general, a double period and a mean range of less than 0.15 millivolt per kilometer.

In the second part of the paper to be published in a later number of the *Journal Terrestrial Magnetism*, a comparison by months, for the period 1924 to 1926 inclusive, between the mean diurnal-variation of the north-

ward earth-current component and rate of change of the *Y*-magnetic component, for the same period at Watheroo shows that the amplitudes are proportional and that the phase-agreement is very close throughout. The phase-agreement between the eastward earth-current component and the rate of change of the *X*-magnetic component is as close as the accuracy of the data warrants, whereas the variations in *X* are distinctly out of phase with the variations in the eastward earth-current component, which is contrary to what was found by others in studies of the Berlin and Ebro earth-current data.

Values of earth-current potentials computed according to the method of Chapman and Whitehead are about six times as great as the observed values, and the two principal harmonics have a phase-retardation of about one hour. A similar difference was found by Chapman and Whitehead for the data at Berlin and at Ebro. The higher-order harmonics, however, seem to be in better phase-agreement. Examples of some unexpected extraneous effects having a 24-hour period, which were disclosed by the records obtained at Watheroo, are given. It is possible that the complexity of some earth-current data obtained at other places may in part be due to similar causes.

List of recent publications. H. D. Harradon. *Terr. Mag.*, vol. 32, 190-200 (September-December 1927); vol. 33, 59-64 (March 1928); 114-120 (June 1928).

This list is a bibliography of current literature relating to (A) terrestrial and cosmical magnetism, (B) terrestrial and cosmical electricity, and (C) miscellaneous subjects allied to (A) and (B). The compiler has prepared in many cases for the more important publications brief abstracts which are included with the references.

Earth-resistivity measurements in the Lake Superior copper country. W. O. Hotchkiss, W. J. Rooney and J. Fisher. *Amer. Inst. Min. Metal. Engin., Tech. Pub.* No. 82, 15 pp. (1928).

This paper covers essentially the same ground as that by W. J. Rooney which is abstracted on page 262 of this report.

On terminology and symbols in atmospheric electricity.¹ H. F. Johnston.

Brief comments on terminology and symbols proposed by Maurain with suggestions for additional symbols needed for the elimination of existing ambiguities caused by the use of the same symbol for several different atmospheric-electric elements.

Principal magnetic storms and earthquakes recorded at the Watheroo Magnetic Observatory, January to October 1927. H. F. Johnston. *Terr. Mag.*, vol. 32, 177-179 (September-December 1927).

Principal magnetic storms and earthquakes recorded at the Watheroo Magnetic Observatory, January to March 1928. H. F. Johnston. *Terr. Mag.*, vol. 33, 108 (June 1928).

Absolute potential-gradient observations at Watheroo Magnetic Observatory.² H. F. Johnston.

In the series of observations reported upon and made between September 23 and December 8, 1927, observations were taken simultaneously at the original standardizing field-station (No. 1) and at a new one (No. 2), while

¹ Report prepared for the meetings of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union at Prague, September 1927.

² Presented at the meeting of the Australasian Association for the Advancement of Science, Hobart (Tasmania), January 17, 1928.

at the same time the potential of the collector attached to the potential-gradient apparatus mounted in the atmospheric-electric building about one-sixth of a mile distant was recorded by means of a quadrant-electrometer. The summary of the thirty-three sets of simultaneous comparisons between the two stations gives an average of 0.92 for the ratio of the value obtained at station No. 1 to that at station No. 2. The difference between the two stations was that the clearing at the second station was very much greater and the collector had its radioactive material arranged symmetrically in a vertical plane.

The author concludes that in addition to the essentials specified in the paper of 1926 at the Perth meeting, the following also appear to be indicated from the above investigations: (1) Collector should be of such shape that the ionizing agent is symmetrically arranged in a vertical plane; (2) for a particular set-up the collector-activity should be such that half-value potential is reached in 30 seconds; and (3) all vegetation should be cut close to ground over a large area, at least 50 meters in radius from the collector as well as any growth over 0.75 meter high in a much larger radius, perhaps 150 meters.

Redetermination of reduction-factor at Watheroo, for use with atmospheric potential-gradient records. H. F. Johnston and F. W. Wood.

A preliminary examination of the electrograms for the years 1924, 1925 and 1926 having suggested the possibility of a systematic insulation-leak in the collector-system of the potential-gradient recorder during the winter at Watheroo and exhaustive tests having indicated the absence of any leak of sufficient magnitude to cause a perceptible lowering of the recorded potential except in the rare instances when a spider-web became attached from the collector-arm to earth, a critical examination was made of the essential features of the method of standardization employed. It became apparent that there was possibly an error of a small percentage in the accepted value of the reduction-factor for the following reasons: (a) A single disc collector used face downward might be a source of indefiniteness; (b) the area of ground cleared around the station might be somewhat inadequate; (c) the site of the station was in a slight depression with respect to the immediate surroundings; and (d) the collector might not be sufficiently active to overcome lowering of the registered potential by leakage across the sulphur-insulators. Although leak-tests had always been performed during standardization-observations, these were far from satisfactory as convincing evidence of the magnitude of the leaks, owing to fluctuations in the potential of the wire (without collector) through induction, and loss of charge due to dispersion. It was believed that the leak was never more than 1 per cent per minute but, because of the reasons above mentioned, the leak-tests which were performed did not give definite evidence to this effect.

A new station (No. 2) therefore was established between the original station and the atmospheric-electric observatory and to the north of the line joining these. The ground was completely cleared of all trees and bushes over an area 80 meters in radius, and all scrub higher than 0.75 meter in the surrounding area to a distance of 150 meters from the center of the clearing. It is estimated that the distortion of the Earth's field at the collector from other sources is less than 1 per cent. The ground is quite level but has a gentle upward slope toward the east of 15'. The supporting posts are 40 meters apart, and special large sulphur-insulators were made to take the strain of the collector-wire while still giving adequate insulation.

The electrometer-earth is buried in a layer of clay placed beneath the collector and the observing-shelter is near the eastern supporting post.

The increased capacity of this collector-system compared with that of the original station required that a more active collector be used. Two of the standard disc field-collectors were joined back to back and connected to the stretched wire with their centers at the required height. With these two collectors the system reached half air-potential from zero in about 30 seconds. A Wulf recording bifilar electrometer of sensitivity 19 volts per millimeter was used to make continuous records at this station and one of the usual D.T.M. C.I.W. electrometers of 1.1 volts per millimeter sensitivity was used for standardizations.

The sets of reduction-factor observations taken since September 1927 gave the value of the reduction-factor for station No. 2 as 1.13 ± 0.02 . Simultaneous observations taken at the original station give a ratio between stations of 1.09 ± 0.008 .

In order to place the criterion for admissible insulation-leak on a more substantial basis, the capacitance of the whole system as in operation was measured, using a standard cylindrical condenser, the values obtained being 149 cm. and 268 cm. for stations 1 and 2, respectively. Eye-observations were obtained of the growth of potential of the collector at each of the field-stations. From these data the conductivity a of the collector was determined by the method used by Cairns and Builder (see p. 241). The value of r , the insulation-resistance, could not be determined from tests performed in the field, since these are affected by induction and dispersion. The method adopted was to measure the leak of the sulphur-insulators indoors by using a Gerdien condenser to supply a capacity equivalent to that of the stretched wire, and connecting up the insulators as in the field set-up. A leak-rate of 0.12 per cent per minute was obtained for the insulators of No. 1 station, which together with the capacitance of that system gave a value for r of 3.10×10^{14} ohms. A rate of leak of 0.23 per cent per minute was obtained for the insulators used at No. 2 station, which for a capacity of 268 cm. indicates an insulation-resistance of 8.83×10^{13} ohms. These values of r were used in computing the value of a for the two stations, and these were 3.55 E.S.U. for the single collector and 6.36 E.S.U. for the double collector.

Evaluation of the effects of various rates of leak on the finally recorded potential indicates a permissible leak of up to 1.4 per cent per minute, and a lowering of only 0.1 per cent in the recorded potentials for the present state of insulation.

A Wulf bifilar recording electrometer was run continuously for 1,800 hours at station No. 2, and while unfortunately for the reliability of the results obtained by this instrument there were several variable factors of appreciable magnitude, frequent leak-tests and regular cleaning of the wire to keep it free of gossamer-spider short-circuiting webs minimized the effects of these so that a large part of the records could be used.

Finally, the error of individual hourly scalings of the electrograms was about 2 per cent (with a sensitivity of 19 volts per millimeter), so that the reliability of the results to within a small percentage is doubtful. The mean value thus obtained agrees very well with that obtained from standardization-observations, and while a diurnal (and possibly seasonal) variation of a low percentage in the reduction-factor is indicated in view of the uncertain thermal effects mentioned above, further and more accurate observa-

tions are planned to determine whether the apparent variation observed is real or results from instrumental or other causes.

List of publications of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, 1904-1927. J. J. Kolar. Washington, D. C., Carnegie Inst., 39 pp. (December 31, 1927).

This list gives titles of some 628 papers and contributions to scientific societies, 24 annual reports, and six major publications in magnetic and electric results prepared during 1904 through 1927 by members of the staff of the Department.

Principal magnetic storms recorded at the Huancayo Magnetic Observatory, January to April 30, 1928. P. G. Ledig. *Terr. Mag.*, vol. 33, 107-108 (June 1928).

On the method used for analyzing radioactive decay-curves obtained aboard the *Carnegie*. S. J. Mauchly.

This note on the practical application of the method, developed by W. F. G. Swann while associated with the Department, for determining the radium-emanation content of sea-air was prepared to facilitate the use of the method in the ocean-work during Cruise VII and in answering inquiries regarding it from other investigators. The analysis of a typical set of radioactive decay-curves obtained by observations made on the *Carnegie* is given. Each daily curve used in the formation of a mean curve is plotted, and from each of these daily curves ordinates at regular intervals are scaled, from which a mean curve is made. In the analysis of these curves n_a , n_b , n_c , represent the numbers of positively charged atoms of radium A, radium B and radium C, per cubic centimeter of the atmosphere.

Assuming each decay-curve to be composed of components η_1 , η_2 and η_3 , in varying proportions, and the curves for η_1 and η_2 are plotted with arbitrary values, it turns out that for both these component-curves the slope is practically zero at 22 minutes after end of collection of deposit. Therefore the whole slope of the experimental curve at 22 minutes is due to η_3 . Thus the original curves may be simplified into curves involving only η_1 and η_2 . By solving as simultaneous equations the equations of these curves, the values of n_a and n_b may be then obtained.

The method is given in which the quantity n_a is corrected to compensate for the fact that some of the alpha-particles drawn to the surface of the collecting foil are absorbed by the metal foil and others strike the wall of the ionization-vessel before completing this range. Similarly it is shown that some of the positive atoms of radium A in the atmosphere have combined with the negative ions of the air and are not included in the value obtained from the calculations, and the correction for this effect is indicated.

Some observations of atmospheric-electric potential-gradient on mountain peaks in the Peruvian Andes near Huancayo, Peru. W. C. Parkinson. *Terr. Mag.*, vol. 33, 15-22 (March 1928).

In order to supplement the scanty data on atmospheric potential-gradient on mountain peaks, continuous records were obtained at two stations near the Huancayo Magnetic Observatory of the Department. The first station (Matahuata) was 500 feet and the second (Cerro-de-Ahuac) was 2,200 feet above the Observatory. Curves showing the diurnal variation during fine weather at the two stations and also at the Observatory base-station are given and briefly discussed.

Note on some photographs of lightning-discharges made at the Huancayo Magnetic Observatory. W. C. Parkinson. *Terr. Mag.*, vol. 33, 23-25 (March 1928).

The photography of lightning-discharges affords valuable data for the solution of some fundamental problems in atmospheric electricity. In this note description is given of the methods used to obtain photographs on motion-picture film of lightning flashes at Huancayo, a location very suitable for this work. Specimen photographs are given and briefly discussed and the necessity for further work indicated.

The correlation of radio reception with solar activity and terrestrial magnetism: II. G. W. Pickard. *Proc. Inst. Radio Eng.*, vol. 15, 749-766 (September 1927).

This is essentially a reprint of the paper already abstracted on pages 207 to 209 of the annual report for 1926-27.

The relation of radio reception to sunspot-position and area.¹ G. W. Pickard. *Proc. Inst. Radio Eng.*, vol. 15, 1004-1012 (December 1927).

From discussion of periodic daily averages for a number of solar rotations, the meridian transit of a sunspot-group is usually accompanied by a depression of night-reception and (with the exception of 1926 and early part of 1927) a slight increase in the day-field. The recovery of the night-reception depression, at least during a sunspot-maximum, is rarely completed before the next depression occurs. These depressions quite definitely accompany disturbances of terrestrial magnetism and less definitely the central passage of sunspot-groups, but in neither case is it warranted to assume that the connection is one of cause and effect. However, the relation of reception to terrestrial-magnetism is so definite as to indicate that disturbances of these two arise from a common and nearby cause, an electrical charge in our atmosphere.

Some correlations of radio reception with atmospheric temperature and pressure.² G. W. Pickard. *Proc. Inst. Radio Eng.*, vol. 16, 765-772 (June 1928).

Night-reception and temperature at the receiver are found directly related, maximum reception being associated with maximum temperatures and vice versa. The temperature-effect appears to be local to the receiver, for no definite relation was found between temperature at the transmitter and receiver. A correlation between night-reception and pressure was also found, signal-strength increasing as areas of low pressure passed over the receiver, and decreasing with the passages of high pressures.

Investigation of compass-deviations produced by rolling. W. J. Peters.

This investigation has been conducted experimentally and theoretically with a view to determine the amount and direction of deviation, permanent during observation, that might result from Sir William Thomson's "kinetic equilibrium-error." In Lord Kelvin's paper³ as well as that of S. G. Starling,⁴ who also investigated the same deviation, only the instantaneous direction of the magnetic field resolved in the plane of the tilted compass-card is considered, and the lack of symmetry that exists when opposite tilts of equal amplitude occur on other than cardinal headings has not been taken into account nor, of course, the resultant quasi-permanent deviation.

¹ Presented before the International Union of Scientific Radiotelegraphy, Washington, D. C., October 14, 1927.

² Presented before the International Union of Scientific Radiotelegraphy, Washington, D. C., April 19, 1928.

³ *Mathematical and Physical Papers*, vol. 4, 464-469 (1910).

⁴ *Phil. Mag.*, vol. 32, 461-476 (1916).

The experiments consisted principally in swinging various types of marine compasses in wooden swings, especially constructed to swing in any particular vertical plane corresponding to any desired magnetic heading of a ship. One of these swings has been designed so that instruments may be installed on a platform that tilts with precisely the same angle as the swing or on another platform that remains level throughout the swinging. On the intercardinal headings quasi-permanent deviations were observed, ranging from $0^{\circ}1$ to $0^{\circ}9$ during a continuous swinging through an arc of 3° on either side of the equilibrium-position, and which amounted to approximately 4° to 6° when the arc of swing was increased to 17° on either side.

Besides the various marine compasses used in the experiments, a special compass was constructed in the shop of the Department to verify conclusions of the theoretical investigation. Experiments with this instrument, which is a crude apparatus, roughly confirm the magnitude of the quasi-permanent deviation calculated from the conditions of the experiment, that is, from the amplitude and period of swing, the magnetic moment and the moment of inertia of the floating magnet-system, the damping action of the liquid, the heading or direction of the plane of swinging, and the inclination of the Earth's field (dip).

As the theoretical investigation progresses it may reveal the desirability of more experimenting under additional or different conditions.

That such large deviations as were given by these experiments do not appear in actual compass-observations made aboard the *Carnegie* at sea is explained partially by the facts: (a) The plane of apparent level through the pivot of the compass is inclined to the true or gravitational at an angle about twice as large in the swing as on the ship for the same amount of roll, even for the highest instrument, the marine-collimator, about 18 feet above the axis of roll; (b) the amplitude of roll of the ship at sea is not constant; (c) the mean roll extending over the usual period of observation is surprisingly small as compared with maximum roll which occurs during the same time and from which one usually makes his mental estimate of the amount of motion. The mean roll during 18 observations that were made on the *Carnegie* between January 14 and March 12, 1920, inclusive, is $4^{\circ}1$ whereas the mean maximum for the 18 was $9^{\circ}3$ as determined from the automatic gyrostat-recorder. The maximum roll was frequently 20° . The mean roll as noted by the clinometer, about 11 feet above the axis of roll, is $5^{\circ}4$.

Earth-resistivity measurements in the Copper Country, Michigan. W. J. Rooney. *Terr. Mag.*, vol. 32, 97-126 (September-December 1927).

During the summer of 1927 the Department and the Michigan College of Mining and Technology engaged in conducting jointly a series of earth-resistivity measurements in the Copper Country of northern Michigan, where the geological structure is well known, to determine the value of measurements of resistivity and its variations as indications of the geological structure below the surface. The work done may be roughly divided in two parts: First, measurement and study of the variations in resistivity with depth, or with volume, to establish such general relations as exist between the two; and, second, the determination of the resistivity of specific rock-flows, in order that more fundamental data be made available as an aid to the interpretation of the results of the former type of measurement.

The results of the first part of the investigation bear out the evidence from previous work that resistivity-determinations may be used to advan-

tage in determining the location of certain underground discontinuities. The data obtained in the second part on the resistivity of specific rocks are also in line with previous results. The resistivity of porous, sedimentary rocks was usually under 20,000 ohms per centimeter cube, while traps and associated rocks of volcanic origin were found to have resistivities from five to twenty times as great.

Earth-resistivity measurements and their bearing on the location of concealed geological discontinuities.¹ W. J. Rooney.

A review of the earth-resistivity investigations of the Department, 1924-27, shows a consistent relationship between the variations of resistivity with depth and the geological structure of the regions surveyed. The possibility of using resistivity-determinations to locate certain types of discontinuity in vertical structure is shown by six specific experiments in Washington and in the Copper Country of Michigan. Results indicating discontinuities at depths beyond 1,000 feet have been secured, but independent determinations to confirm the resistivity-indications are seldom available for depths much greater than 100 feet. Hence the depth limit for practical application of the method is uncertain. Given a fairly uniform lateral distribution of material, resistivity-measurements made on the surface will disclose quite accurately the distance to underground water and the depth of overburden, and may be used to determine the thickness of rock-strata, provided the rocks differ sufficiently one from the other. The resistivity of soils varies widely with composition and with the amount and character of the solutions they contain.

A discussion of a proposed biological and chemical program to be carried out during the seventh cruise of the *Carnegie*. H. R. Seiwel.

In planning the biological program of the seventh cruise of the *Carnegie*, it was deemed advisable, since the line of investigation must necessarily be limited, to make an intensive study of the environmental conditions of a selected category of marine life, namely, the plankton. Such a study is now required if a better understanding of the nature of the plankton is to be had. Another problem which has an important bearing economically as well as theoretically, is that of the quantitative geographical distribution of the plankton. However, because of certain habits of these organisms, present-day methods of sampling yield very imperfect results and the tedious methods of statistical estimation are no longer justified. Recently more stress has been placed on the relative percentages of different forms in the individual sample than the estimation of the number of organisms in a given volume of water. At present the apparatus which most closely approaches the ideal method of plankton-sampling is the Pettersson plankton-catcher. In quantitative plankton-work it is not only necessary to obtain a representative sample, but the place and depth from which samples typical of a particular region must also be known. Before such data can be worked out, we must learn more about the life history of the organisms, as for example, the relation between environment and the organism itself. In this connection, the seventh cruise of the *Carnegie* furnishes an excellent opportunity for carrying out the following program: (1) The determination of the relative abundance of the great groups of plankton-organisms in various parts of the sea; (2) a study of the chemical fertility of the sea as an indication of productivity; (3) an effort to determine whether diurnal migra-

¹ Presented before the Philosophical Society of Washington, January 21, 1928.

tion exists over the entire world as in certain inshore areas; (4) study and comparison of the metabolic rates of the plankton-organisms in various parts of the world; (5) investigation of the causes of stimulation which lead to breeding, death and decay; (6) investigation as to whether it is considered a typical and characteristic peculiarity in the distribution of the important plankton-crustaceans to be confined to slopes of the continental shelf or of the banks toward deep channels; (7) investigations and descriptions of plankton-communities at different levels in the oceans with analyses of their environmental conditions; (8) investigation of the lethal effects of sunlight, temperature, etc., on plankton taken from various latitudes; (9) comparison between the distribution of plankton and current-systems of the oceans.

The chemical program proposed includes determination of phosphates, silica, oxygen, hydrogen-ion concentration, salinity and possibly nitrates.

This discussion of the plankton, methods and problems touches only the outstanding conditions surrounding this group of organisms and makes no attempt to outline all the important problems in biological and chemical oceanography. The program developed is based upon the feasibility of carrying it out on the *Carnegie* and because of the unique opportunity offered in this field by the proposed route for the seventh cruise of the vessel.

Patterns for conical silk plankton-nets of one meter and half-meter diameters. H. R. Seiwel.

The construction of the conical silk plankton-nets for use on the seventh cruise of the *Carnegie* is described in detail for the guidance of future investigators who may desire to make use of similar equipment. The nets are of two sizes, namely, (a) 1 meter diameter and 4.5 meters long, and (b) 0.5 meter diameter and 2.75 meters long. They are made of Dufour silk bolting-cloth of different meshes according to the kind of plankton to be collected, and are provided with canvas collars at the top and bottom for holding the net-ring and collecting bottle, respectively. Information is given regarding the various materials, dimensions of different parts and patterns adopted after due consideration as the most suitable for the proposed work to insure most economical cutting of the material and to reduce the number of seams to a minimum. Dimensional diagrams of the patterns are given.

Magnetic, atmospheric-electric, and auroral results, *Maud* Expedition, 1918-1925. H. U. Sverdrup. Reprint from Carnegie Inst. Wash. Pub. No. 175 (Vol. VI) 309-524 (1927).

The data, discussions and conclusions given in this report are abstracted on pages 210 and 211 of the annual report for 1926-27.

Solar-radiation observations at Apia. A. Thomson. Mon. Weath. Rev., vol. 55, 266-267 (June 1927).

The solar radiation at Apia has been measured on clear days since January 1925. This article summarizes the results and shows that at Apia the solar radiation transmitted to the Earth's surface is greater during the wet than the dry season. This would indicate that salt particles are probably responsible for a share of the absorption of heat radiation.

Cyclones in the Southern Pacific. A. Thomson. Q. J. R. Met. Soc., vol. 53, 178-181 (April 1927).

The rainy season 1925 to 1926 was notable in the South Pacific for five destructive cyclones. The paths of these cyclones were located, and were

found to be straight lines instead of parabolic. Tidal waves were set up by the wind and the speed of these waves was determined by records of the time the waves reached inhabited islands.

Occurrence of thunder and lightning in the South Pacific. A. Thomson.

A report written at the request of the Royal Meteorological Society for their investigation of the effect of electrical storms in causing static disturbance in wireless.

Niufou a site for observing the total solar eclipse of October 1930. A. Thomson.

Except for an uninhabited islet, the island of Niufou is the only land area in the path of totality of the total solar eclipse of October 21-22, 1930. In September and October it is possible to land instruments at Niufou, and the records at Apia show there is a good chance for having a cloud-free sky at the time of totality.

Pan-Pacific Cooperation in the International Geodetic and Geophysical Union. A. Thomson. J. Pan-Pacific Research Inst., 2 (January to March 1928).

A brief account is given of the meeting at Prague. The necessity of co-operation of the Pan-Pacific Science Conference with world organization is pointed out.

Lasting qualities of small rubber balloons. A. Thomson. Met. Mag., vol. 63, 65 (April 1928).

A note on the advantage of storing balloons separately in envelopes after having dusted them with talcum powder.

Report of the Apia Observatory prepared for the Mandate Commission. A. Thomson.

An account of the activities of the Apia Observatory during 1927, published 1928 on pages 33 to 35 of the "Seventh report of the Government of New Zealand on administration of mandated territory of Western Samoa."

Report on the Apia Observatory, Samoa, for 1924. A. Thomson. Wellington, W. A. G. Skinner, Govt. Printer, 84 pp. (1927).

Report on the Apia Observatory, Samoa, for 1925. A. Thomson. Wellington, W. A. G. Skinner, Govt. Printer, 95 pp. (1927).

These two reports contain, in addition to the magnetic, seismic and meteorological data resulting from records at the observatory for 1924 and 1925, those of atmospheric potential-gradient obtained with the cooperation of the Department.

Tentative magnetic values as recorded at the Apia Observatory for the year 1927. A. Thomson and C. J. Westland. Terr. Mag., vol. 33, 46 (March 1928).

Principal magnetic storms recorded at the Huancayo Magnetic Observatory, April to July 1927. O. W. Torreson. Terr. Mag., vol. 32, 181-182 (September-December 1927).

Principal magnetic storms recorded at the Huancayo Magnetic Observatory, August to December 1927. O. W. Torreson. Terr. Mag., vol. 33, 48-51 (March 1928).

A transmitter modulating device for the study of the Kennelly-Heaviside layer by the echo-method. M. A. Tuve and O. Dahl. Proc. Inst. Radio Engineers, vol. 16, 794-798 (June 1928).

This paper describes a method for obtaining a much improved type of transmitted signal for use in the study of the radio reflections from the ionized layer in the upper atmosphere by the echo-method. "Peaks" of

very short duration and proper spacing must be transmitted, in order to give completely resolved "peaks" at the receiver, especially when there are multiple reflections or when there is an extremely low reflecting layer. The method described for modulating the transmitter is based on the sudden pulses of plate-current which occur in an unbalanced multivibrator-circuit (*vide* H. Abraham and E. Bloch. *Annales de Physique*, vol. 9, 1919, p. 237). Such transmission has given results quite free from ambiguity with respect to possible interference of the waves reaching the receiver by different paths. Typical recorded signals are reproduced.

On need of measurements of dust-content in the study of atmospheric-electric phenomena.¹
G. R. Wait.

The expectation that the presence of dust-particles and Aitken's nucleation-centers in the atmosphere are effective in altering the values of certain of the atmospheric-electric elements is borne out by available but scanty observational data. Observations made at the Watheroo Magnetic Observatory with an Aitken counter, loaned by the Commonwealth Meteorological Bureau of Victoria, show the extent to which the Aitken nucleation-centers may be effective in altering the two conductivities and the potential gradient of the atmosphere. The results suggest need of additional comparisons, not only at this station but at many others as well, to determine to what extent we shall be able to correct the atmospheric-electric data for the presence of nucleation-centers.

Most data now favor the assumption that the Aitken apparatus counts only hygroscopic particles and the Owens apparatus only dust-particles. This being so, then it is unlikely that any definite relationship between the two instruments holds. At a number of different stations, observations show the number of particles by the Aitken instrument to be approximately one hundred times those by the Owens instrument. Thus at Watheroo it was hardly possible to make a count with the Owens counter. The number found at the laboratory in Washington with an Owens counter has never exceeded 200, while the Aitken instrument gave in general from 10,000 to 20,000. It is likely then, in spite of the larger size of the dust-particle, that a more definite relationship at these stations will be found between the atmospheric-electric elements and the Aitken nucleation-centers.

Effect of insulation-leak upon the registered potentials by a potential-gradient recording apparatus. G. R. Wait.

Suppose a potential-gradient collector system, having an electrical capacity and resistance to earth corresponding to C and r respectively, and with a collector whose activity in electrostatic units is a , is placed at a point in the atmosphere where the potential is V , then, assuming that Ohm's law holds in such a case, the differential equation $C \, dv/dt = a(V - v) - v/r$ will give the rate at which the system will assume a charge. When steady conditions have been reached $v/V = ar/(1 + ar)$ gives the ratio of the potential being recorded to the true potential of the air. The nearness to which the true potential will be recorded depends, then, upon only the two factors, namely, collector-activity and the resistance between the collector-system and earth. In other words, the insulation-resistance demanded by a given system depends upon the activity of the collector used. In practical work with it, if one makes an insulation-leak test by charging the collector-system (collector being removed) to a potential V_0 and notes the rate at which

¹ Report prepared for the meetings of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union at Prague, September 1927.

the potential decreases, then, if the charge on the system is altered only through insulation-leak, one may compute the per-cent error in recorded potentials for different per-cent leaks per minute, by means of the relationship

$$v/V = at/[C \log_e (V_o/V_i) + at]$$

At the Watheroo Magnetic Observatory, the activity of the collector now in use was found to be between two and three electrostatic units and the capacity of the potential-gradient apparatus to be about 80 cm. The following table, based upon these constants, gives the per-cent error of recorded values of potential for different leaks per minute. An idea of the insulation-resistance necessary to maintain on such a system may be had by computing the resistance for the different rates of leaks per minute, using the well-known equation, $r = t/[C \log_e (V_o/V_i)]$.

Insulation-resistance in E.S.U.	Per-cent leak per minute	Per-cent error in recorded potential
375	0.2	0.1
125	0.6	0.4
75	1.0	0.7
50	1.5	1.0
37	2.0	1.3
25	3.0	2.0
15	5.0	3.3
7	10.0	6.6
5	15.0	7.7
3	20.0	13.0

Electrical resistance and magnetic permeability of iron wire at radio frequencies.¹
G. R. Wait, F. G. Brickwedde and E. L. Hall.

Mitiaeve observed (Zs. Physik, vol. 38, 716-726, 1926) that the high-frequency resistance of iron wire underwent a critical change at about 100 meters wave-length. This he considered a confirmation of the results of Wwedensky and Theodortschik on the critical change in permeability of iron. In view of contrary results on permeability by Wait at the Department (see last year's report, p. 212) it was decided to investigate the high-frequency resistance.

The resistance of wires intermediate in size between those used by Mitiaeve were measured by the resistance-variation method as described in Bureau of Standards Circular 74. The investigation was carried out between 79 to 120 meters. No critical change within the observable accuracy was detected.

The difference in results between those of Wwedensky and Theodortschik and those of Wait on the permeability of iron in alternating fields might be due to a difference in the kind of iron. The variation in permeability of a sample in which the phenomena had been observed by Wwedensky and Theodortschik was determined with the same apparatus and under the same conditions as by Wait. Smaller fields and various methods of binding the sample were also tried. In no case was a critical variation observed.

¹ Presented by G. R. Wait at the meeting of the American Physical Society and A.A.A.S., Nashville, Tennessee, December 28, 1927. This investigation is a cooperative one by the Bureau of Standards, represented by F. G. Brickwedde and E. L. Hall, and the Department, represented by G. R. Wait.

TORTUGAS LABORATORY¹

In accordance with authorization by the Trustees of the Institution, investigations were conducted at the Tortugas Laboratory during the summer of 1928. Upon invitation, Dr. Wm. H. Longley, of Goucher College, served as executive officer during the season. Mr. John W. Mills, chief engineer, remained in charge of all equipment and aided in securing necessary supplies.

The following investigators studied at the Laboratory during the season, and important advance was accomplished in a number of researches carried on from previous years.

Paul Bartsch. U. S. National Museum. Breeding experiments with cerions. August 16 to August 20.

L. R. Blinks. Rockefeller Institute. Electrical resistance of *Valonia*. May 30 to July 23.

Paul S. Conger. Carnegie Institution. Diatom studies. May 30 to July 11.

M. W. de Laubenfels. Oberlin College. Experiments concerning cellular behavior and physiology of sponges. May 30 to August 6.

Caswell Grave. Washington University. Influence of light on the behavior and metamorphosis of the larvæ of ascidians. June 27 to August 6.

Myron Gordon. Cornell University. Experimental studies in the biology of coloration in fishes. May 30 to July 9.

Ivey F. Lewis. University of Virginia. Studies of brown algæ. May 30 to July 9.

Warren H. Lewis. Carnegie Institution. Comparative study of fish blood. June 13 to July 9.

W. H. Longley. Goucher College. Observations upon ecology of Tortugas fishes. May 30 to August 20.

Oliver H. McCoy. Johns Hopkins University. Life histories of marine trematodes. May 30 to August 20.

A. S. Pearse. Duke University. Observations on certain littoral and terrestrial animals at Tortugas. July 11 to August 20.

A. A. Schaeffer. University of Kansas. Ameba studies. May 30 to July 9.

Harry Beal Torrey. Cornell University Medical School. Further study of the control of regeneration in *Pennaria* by thyroxin. July 25 to August 6.

Report on the Cerion Breeding Experiments at the Tortugas, by Paul Bartsch

Dr. Bartsch's visit at the Station this year was a short one—arriving on August 17, 1928, and leaving with the *Dohrn* on the closing of the laboratory, August 20. However, sufficient time was granted him in this period to make the examination of the Cerion colonies.

A careful examination of the contents of the little islands showed the presence of some young individuals, but no adult hybrids.

An examination of the cut-down cages, however, revealed one adult of the much looked for cross between *Cerion viaregis* and *C. incanum*. It will be remembered that considerable criticism was expressed because Dr. Bartsch, in his original crossing experiments, had employed large groups (500 individuals) of each of the two species, and doubt was expressed as to whether the organisms which he claimed to be crosses were really crosses. Some of

¹ Situated at Tortugas, Florida.

the critics held that they might be mutations of one of the two species involved. To settle this, the individual cage and island method was resorted to. These restricted areas were stocked with a virgin individual of each of the two species mentioned above. The results were what Dr. Bartsch expected, a perfect vindication of the mass experiment, for the adult hybrid obtained in the cage is in every way identical with those secured from the mass experiment on New Found Harbor Key. This of course was to be expected, for in no colony of *C. viaregis* or *C. incanum* has any form appeared comparable in appearance to the hybrids in question. Thousands upon thousands of specimens were examined in all these colonies, and never once has an individual turned up which might have given one the slightest doubt as to the specific identity of the individual in question. A more complete report on this hybrid and the other happenings in the hybrid colony will follow shortly in connection with a paper now almost completed on the dissection of 100 hybrid Cerions.

While at the Tortugas, Dr. Bartsch had sufficient time to spend part of a day under sea with the diving hood and the camera, going over the fields photographed in the years gone by, in order to have a continuous record, of what is happening on the reefs, impressed upon photographic film.

Electrical Measurements on Organisms, by L. R. Blinks

The present season's work was in direct continuation and refinement of last season's, using chiefly *Valonia ventricosa*. The electrical resistance of these large cells to direct current was carefully measured and its variability determined, especially in relation to the voltage applied. The resistance component, as distinct from polarization, was made evident by photographic records of the excursions of an Einthoven galvanometer connected into the Wheatstone bridge. These records show the change of resistance as the current flows and also, when the circuit is opened, the amount of back voltage which has developed in the protoplasm. A large series of these records was developed and their study will be of value in the theory of ionic movements in protoplasm.

The occurrence of this variable resistance in cells freshly gathered is now taken to be caused by a degree of injury over part or all of the surface, which allows a small current to pass when that surface is negatively charged. Its resistance rises when the outer surface is positively charged. Such a condition is exemplified completely when one end is killed with chloroform, and less so usually in the fresh cells. As the cells are kept, they become less sensitive to changes of voltage, and we may assume the injury is recovered from. Some cells show a change of total resistance of 100 per cent or more when the voltage is increased from 25 to 100 millivolts, while later the increases may become negligible over this range. In the former case a considerable part of the current is being carried through some part of the protoplasm; in the latter, little or none seems to go there, being confined to the cell wall.

The identification of the ions carrying the current in the former case was attempted by varying the content of the solutions bathing the ends of the cells. No discernible change seemed to be caused by the substitution of

NaCl, KCl, $MgSO_4$, or a sulphate sea-water for normal sea-water, though in certain cases the replacing of normal sea-water suddenly caused a marked rise of resistance at all potentials. This effect deserves further study. Calcium chloride is quickly toxic, but the cells recover promptly from a short exposure to it. The curves of this injury and recovery, taken concurrently with the variation of the bio-electric potential (shown by a Compton electrometer and the zero position of the galvanometer in the bridge), are expected to throw light upon the destruction and reformation of the protoplasmic layers involved. Injury and recovery from the application of voltages up to one half volt were likewise recorded.

Some readings of the cell capacitance of *Valonia* in alternating current over a range of frequencies were taken, and for comparison, impedance measurements over the range were made with discs of *Dictyosphaeria favu-losa*, an alga closely related to *Valonia* but having smaller cells arranged in regular sheets of tissue.

An attempt was made to measure the action current produced in the rhythmic muscular contraction of *Cassiopeia xamachana*. It was possible to record this in the manner of an electrocardiograph, using the maximum sensitivity of the galvanometer. The effective voltage is extremely small (a fraction of a millivolt). Magnesium sulphate, introduced to depress muscular contraction in part of the ring of tissue, caused the appearance of much larger currents, but these are attributable to diffusion potentials of this salt against sea-water, brought in varying contact by the mechanical movements of the adjoining tissue.

Diatom Investigations at Tortugas Laboratory 1928, by Paul S. Conger

Investigations on the diatoms were continued at the Tortugas Laboratory during the first half of June. Work of the nature of that carried on in several preceding seasons was resumed this year, toward a study of possible seasonal fluctuations in the diatom flora in the vicinity of Tortugas. To this end approximately 70 samples of bottom and plankton material were taken from more than 50 stations varying in bottom, tidal and current conditions. Several plankton samples were taken on different days at certain of the stations to note any changes. A considerable variety of bottom and plankton feeding organisms were collected in order to ascertain from their stomach contents to what extent diatoms, and what kinds of diatoms, might serve as their food.

An attempt was made to obtain a more accurate knowledge of the actual seasonal and specific diatom flora produced at Tortugas by planting tile at twelve different stations under varying conditions of the water and the bottom. Fine unglazed 4 by 6 inch tile were used for this purpose and were attached to a small brightly colored float which would enable them to be found later. One series was allowed to remain in the water for a period of 10 days, at the end of which time a very appreciable growth was found on the surface. At this time the tile was pulled up slowly through the water, brushed off with a fairly stiff brush, rinsed into a beaker, and replanted. The contents of the beaker were bottled in a small vial. This second series

of tile was allowed to remain to the end of the season, or a period of two months. The samples thus obtained will be studied carefully during the following winter.

Advantage was taken of a trip to Tortugas to go by way of Tampa, to obtain a series of samples from the west coast of Florida, a region almost entirely unrepresented in our collections heretofore. It was especially desired to obtain this material for comparison with the Tortugas flora, as the two floras promise to be quite diverse. The ramifications of Tampa Bay in the region of Tampa and St. Petersburg were well covered and 30 samples were collected, the material proving rich in diatoms, both in species and individuals. The water was thick with plankton, and the richness of this area in diatoms may perhaps account for the abundance of marine life there and of fish life in particular.

One of the laboratory motor boats was made use of on the day previous to sailing to obtain half a dozen samples in the vicinity of Key West for purposes of comparison with the Tortugas flora. The most gratifying results of the stay in Florida were the rich collections obtained in the region of Tampa.

Experimental studies in the biology of coloration in fishes, by Myron Gordon

In connection with the general program of research into the biology of coloration in fishes with which I have been concerned for the past four years, an investigation of the possibility of utilizing some of the coral reef fishes of Tortugas, for special phases of the work, was made during six weeks of the summer of 1928. While at Cornell University emphasis has been placed upon problems of inheritance of various color patterns, chiefly in the Mexican killifish, *Platyæcilus maculatus*, recently certain physiological tests have been employed in an attempt to get at the limits of color change within different genetical strains. Together with these latter experiments, others were planned to induce the development of melanin in those varieties which normally do not possess any, or possess some in only a limited degree. The organic substances used in these experiments are those which recently have been given as the probable precursors of melanic pigment in the animal body.

About 70 species of fishes were observed at Tortugas, of which 60 were taken and preserved for further study. Photographs of the living fishes were made by placing the animals in a specially constructed aquarium. These pictures, of which about 100 were made, shall serve as a record of the general color pattern of the fishes studied.

As a result of the above survey it has been concluded that the following species possess the necessary qualities which would make further work profitable, particularly physiological reaction to chemical stimuli: *Halichæres bivittatus*, Slippery-dick; *Gillellus semicinctus*, White jugular; and one of the Apogonids, a Cardinal-fish. The first is extremely common, hardy in captivity, small enough for binocular work and exhibits a wide variety of color patterns both in the sea and in the laboratory. *Gillellus*, while comparatively rare in catches, seems to be an excellent species for the



FIG. 1. *Halichoeres bivittatus* (Slippery dick). a, In the dark phase. b, In the light phase.



FIG. 2. *Gillellus semicinctus* (White jugular).



FIG 3 *Apogonidae* (sp. ?) Cardinal fish. a, In the dark phase b, In the light phase.

experiments designed to induce melanic pigment development, as this fish is decidedly white, having but a few melanophores. The last, the Cardinal-fish, is a form in which melanic pigment is developed to an extraordinary degree. The melanophores are quite large—their processes, radiating from the center, and containing the melanin granules, are extremely long and easily observed. The above types by no means exhaust the useful list.

It is hoped, now that the animals are known, and with a well-equipped laboratory, that work on this problem may go on in the future with but a minimum loss of time.

Continuation of Study of the Influence of Light on the Behavior and Metamorphosis of the Larvæ of Ascidians, by Caswell Grave

Symplegma viride, the species with which the discovery was made last year that light in some manner conditions metamorphosis of the larva, was not available in sufficient numbers for experimental studies. *Polyandrocarpa tinctoria*, a species nearly related to *Symplegma*, proved to be an ideal one for the investigation planned. Colonies of this species thrive in the environment provided by a live-car at the laboratory dock and thus make it possible to use the same colonies as the source of material throughout the investigation. The larva is small, is liberated in large numbers at a convenient hour almost daily and its free-swimming period is relatively long. Under laboratory conditions, none has been observed to undergo metamorphosis in the course of the day of liberation, but all larvæ transform during the night following their liberation by the parent. In the morning, metamorphosed ascidiozooids are found floating at the surface of the water in which they were swimming at dark the previous evening.

By experiment it was found that this larva can be induced to make attachment and metamorphose, in about 66 per cent of the cases, about 70 minutes after liberation, if the larvæ, soon after being set free, are given 25 to 30 one-minute "doses" of light, each followed by a one-minute "dose" of shadow. The remaining 34 per cent undergo metamorphosis within about 3 hours of the completion of the series of exposures to light and shadow.

A typical experiment, made after a satisfactory method had been developed by many trials, is outlined as follows: On August 3, the numerous larvæ that had been liberated between 12^h 05^m and 12^h 30^m p.m. were collected with a pipette and placed in three shell-vials, 2.2 cm. in diameter and 5 cm. in height, containing sea-water to a depth of 3.5 cm. These vials were placed about one meter apart on a table near the center of a large laboratory that was lighted from three open east windows. All other sources of light were closed. Rain clouds covered the sky, reducing the diffuse light of the room to an unusually low intensity. Two of the vials, containing 56 and 37 larvæ respectively, constituted "controls" for the results of the experimental treatment given the 59 larvæ in the third vial. The vials used as "controls" stood in the uniform light of the room throughout the afternoon. The vial containing the larvæ to be treated was given 30 one-minute exposures to the diffuse light of the room, each followed by a one-minute exposure to darkness, produced by covering the vial with a

tumbler wrapped with black paper, the entire treatment extending from 12^h 33^m to 1^h 33^m p.m. Attachment and metamorphosis of the larvæ began at the end of the twenty-fifth exposure, and 38 larvæ had attached and metamorphosed in 1 minute after the thirtieth exposure. 18 of the remaining 21 larvæ attached and metamorphosed, one by one, within 3 hours of completion of the treatment. Three larvæ did not metamorphose and died the following day.

None of the larvæ in the "control" vials had metamorphosed 5 hours after their liberation. At this time the control vial that contained 56 larvæ was given the same treatment to which the experimental vial had been subjected, with the result that the larvæ began to attach and metamorphose at the thirteenth exposure to light: 1 at the thirteenth, 6 at the fourteenth, 5 at the fifteenth, 3 at the sixteenth, 1 each at the seventeenth, eighteenth and nineteenth, 2 at the twentieth, 3 at the twenty-first and 1 each at the twenty-second and twenty-third. The remaining 31 larvæ retained the larval form until they died the following day.

None of the 37 larvæ of the other control vial had metamorphosed at sun-set (7^h 15^m p.m.)—more than 6.5 hours after their liberation.

Similar experiments with larvæ of three other species of compound ascidians gave results corresponding to those obtained with the larva *Polyandrocarpa*. These are: *Botryllus niger*, *Leptoclinum macdonaldi* and a species of *Didemnum*, provisionally identified by Dr. W. G. VanName as *D. vanderhorsti*. The larvæ of these species differ, however, in susceptibility to the influence of periodic changes in light-intensity, metamorphosis occurring in the most susceptible larvæ of *Leptoclinum macdonaldi* after the fifth one-minute exposure.

In preparation for this experimental study of the relation of light to metamorphosis, it was anticipated that a *quantitative* relation would be found; that the stronger the light to which larvæ were exposed, the more quickly would metamorphosis be induced, hence a heliostat was provided by which a beam of direct sunlight could be delivered vertically into vials containing larvæ. As the work progressed, however, it became apparent that light, to be effective in inducing or accelerating metamorphosis, must be delivered in rhythmic pulses; that it must be alternated at regular intervals with light of lower or of higher intensity or with darkness, and that the duration of exposures to light and to shadow is an important factor in bringing about the internal changes upon which metamorphosis depends. One-minute intervals of light followed by like intervals of shadow were found to be more effective than 30-second or 20-second intervals. Momentary intervals of shadow, one per second, produced by a pendulum 10 cm. in width, swinging between the vial and the source of light, has no effect whatever. Larvæ so treated for 4 hours, continued free-swimming life as long as untreated ones. Direct sunlight of its maximum intensity at the Tortugas is no more effective in conditioning metamorphosis than the diffuse light of the laboratory on a "dull" cloudy day. Both, if steady, do not accelerate the internal processes underlying metamorphosis, but are equally effective if alternated with light of lower intensity. The processes, assumed to take place in the larva during the free-swimming period and to be causally connected

with behavior, attachment and metamorphosis, do not *require* intermittent light for their occurrence; for metamorphosis of the larva of *Polyandrocarpa*, although greatly delayed, finally takes place whether the larvæ be exposed to varying grades of uniform intensity of light or to total darkness. Metamorphosis, however, if not accelerated by exposure of the larva to intermittent light, is not preceded by attachment. Larvæ that pass their free-swimming period in light of uniform intensity or in darkness fail also to develop a final negative response to light and a positive response to "gravity"; while both responses appear in normal behavior and lead the larva to attach and metamorphose at the bottom where the species finds conditions essential to its well being. When metamorphosis is long delayed, it occurs at the surface of the water and the ascidiozooids float unattached and upside down.

Although the nature, mode of function and location of the substances that are involved in determining the responses and orientations of the larva during its free-swimming period, and which also apparently bring about the disruption of the entire larval action system by the processes that constitute metamorphosis, will doubtless long remain unknown, something of the nature of the changes that occur may be indicated by the oriented movements of larvæ while undergoing treatment. During the first several exposures to light and shadow, all larvæ swim actively and continuously at or near the top of the column of water; later, during each exposure to light, they tend to become quiescent and to sink motionless to the bottom but, at the instant the light is interrupted, all larvæ become very active and swim in a dense swarm to the top of the column of water. Before the end of each one-minute interval of shadow, however, they tend to become inactive and to sink to the bottom. It is evident from this behavior that an effective stimulus to energetic swimming movement is produced at the moment of *reduction* of light intensity. It is as if a chemical change, involving the liberation of energy, occurs at the moment of reduction of light intensity and perhaps the reverse change with increase in intensity, involving absorption of energy, but such an assumption requires that the same level of light intensity which, in one case, conditions an anabolic process is the level which, in another case, conditions a katabolic process. Light-adaptation of the larvæ would necessarily constitute an important factor in such an hypothesis.

In the normal habitat of these ascidians it is evident that the behavior of the larvæ is effective in and adapted to bringing about attachment and metamorphosis within a short time after liberation. Their alternate positive and negative responses to light and "gravity" cause them to swim repeatedly up and down between the surface of the water and the bottom; that is, between two effective levels of light intensity, until a final stimulus to attachment and metamorphosis is released.

Experiments concerning Cellular Behavior and Physiology of Sponges,
by M. W. deLaubenfels

During the summer of 1927 at Tortugas it was found possible to force conglomerations of the cells of certain species of sponges, so that small bispecific aggregates were secured and kept alive as much as two weeks, during which time feeble beginnings of metamorphosis appeared. The behavior of the conglomerations being conspicuously different from that of monospecific reuniting masses, much effort was spent this summer in the attempt to analyse conditions involved. No conglomerations were carried further than those of last year, and this seems to be accounted for by certain observations given below.

The three sponges most worked with, pending their naming by their discoverer, Professor H. V. Wilson, may be conveniently designated the red, green and purple species. Each may be conglomerated with either of the other two by a simple technique. Portions of the adult sponges are cut into small bits which are mixed in a bolting-cloth bag and the two species are expressed simultaneously with considerable rubbing between the fingers. The red-green conglomeration upon settling is in masses of a few score cells at most and remains inactive until death sets in within a few hours. The green-purple conglomeration behaves nearly like a monospecific culture with characteristics halfway between those of the green and the purple, though metamorphosing more slowly than either; furthermore, in the course of a few days the cells of the two species gradually sort out into separate masses. The red-purple conglomerates are formed before settling and have a very characteristic flocculent appearance which persists throughout their life; they make feeble attachment to glass and develop flagellate chambers during the two weeks they live.

If cells separately expressed are mixed, they form aggregates with cells of their own species only. They are hindered somewhat by the foreign cells, but starch grains in similar abundance caused as much difficulty.

Cells were expressed, crushed by grinding with fine clean sand, and the filtrate added to expressed cells of other species in such quantity as to give concentrations of one part filtrate to one-thousand parts of water. Extract of the red sponge added to cells of the green, or vice versa, caused instant paralysis (if not death) of the amœbocytes of the species affected, the choanocytes remaining active indefinitely. Extract of the green sponge added to cultures of the purple, or vice versa, yielded no evident result whatever. Extract of the purple sponge added to cultures of the red had no evident effect, but the contrary was not true; extract of the red sponge added to cultures of the purple had a paralytical effect on the amœbocytes and caused the masses of this species to simulate very closely the appearance and behavior of the red-purple conglomerates. Note that the red and the green were most inimical to each other, yet are in the same genus; the purple is in a different family, yet damaged neither. Heating these aqueous extracts caused them to lose their effect, 90 degrees being always sufficient, 70 degrees some times sufficient, while at others even 80 degrees was not enough.

It seems evident that in the bispecific conglomerations the cells of each species involved behave as though there were present the extracts of the

cells of the other species. If such extracts be not harmful, cellular activity eventually breaks up the conglomeration. If the extracts inhibit pseudopodial activity, the conglomeration persists, but no pores, canals or oscula appear, though the choanocytes may form flagellate chambers. It is noteworthy that we have here cells grafted in among cells, and (as a result ?) an effect of protoplasm upon protoplasm more extensive than that involved in grafting a few larger bits of tissue into the body of an animal or plant of another species.

Other experiments were carried on during the summer of 1928, some of which may be briefly mentioned as follows.

Numerous sponges were tried out as to their suitability for regenerating and conglomerating experiments. All the so-called horny sponges, including the sponge of commerce (*Euspongia officinalis*), proved unsuitable. No species was found to be better in the respects mentioned than the red, green and purple species. A *Halichondria* was found to be nearly as good, and conglomerations between it and each of the three principal species were secured.

Reuniting masses of different species were secured and brought in contact with each other in various combinations, but none coalesced. Under these circumstances masses of the same species freely united. Several of the sponges at Tortugas exhibit a diversity of growth-forms, and balls of cells from these were found to unite with each other freely. Attempts were made to determine if balls of cells of the same species, but from widely separated geographical localities, would unite with similar facility, but they failed—due to death of the cells of the sponges that had been transported more than about an hour's distance. Perhaps a special apparatus might be devised to transport them safely.

About 15 species were collected, some by dredging, that were not found in 1927. This establishes the sponge fauna of the vicinity at approximately 55 species.

Numerous efforts were made to find some chemical modification of the sea-water which would favor interspecific conglomeration. Various artificial sea-waters were employed, also various osmotic pressures, temperatures, etc. Hypotonic sea-water down to 80 per cent proved the equal of sea-water; artificial sea-water according to van't Hoff's formula was very nearly equal to natural sea-water, but no medium was found that excelled unaltered sea-water. Among the variations tried were increased alkalinity, increased acidity, increased and decreased osmotic pressure, increased and decreased quantities of the following ions: Na, K, Ca, Mg, Cl, SO₄ and CO₃. Statistics were accumulated as to certain effects of these ions.

A series of parallel experiments was carried on, each one degree warmer than the preceding. The normal range of temperatures where these sponges occur naturally is approximately 22° to 32° C. No significant difference in cellular behavior was found within this range, marked injury appearing, however, below 19° and above 35°. (Regenerating sponge masses were used for this and the following.) Repeated experiments with controls indicated that the greater the light, other conditions being equal, the better the sponge masses fared. Further tests using adult sponges indicated that in

the sunlight each of the three species took much less oxygen from the water about them (using the Winkler test) and released much less carbon dioxide into the water (using pH readings based on use of LaMotte chemical indicators) than in the dark, other conditions being equal. All the tests indicated that considerable photosynthesis was carried on by these sponges.

Studies of Brown Algæ, by Ivey F. Lewis

During the period June 1 to July 9 work was carried on with various Phæophyceæ (Brown Algæ). In this group the phenomenon of periodicity in reproduction offers some unusual phases. In *Dictyota*, particularly, lunar or tidal periodicity has been long known. Reproductive cells mature once (Beaufort, North Carolina) or twice (Wales, England, Naples) during each lunar month. Variations in the periodic cycle in different localities and under different conditions lead to the hope that the stimulus to periodicity may be found, and that the establishment of this inherited behavior tendency may be correlated with environmental factors.

Several species of *Dictyota* are available at the Tortugas. *D. bartayresii*, *dentata*, *cervicornis* and *divaricata* are more or less abundant, while *D. pardalis*, *indica*, *ciliolata* and *dichotoma* occur, but not commonly.

Observations were made on all these species except *ciliolata*, which was not found. The results show that sexual reproduction is completely inhibited during those months when it might be expected. Whether sexual plants appear at other seasons is an open question. The omission of the sexual phase in the life history is rendered possible by the widespread, perhaps universal, occurrence of apospory. The normal life history is as follows. Sexual plants produce gametes, male and female. From the zygote is produced a non-sexual plant, on which are borne numerous tetrasporangia. Each tetrasporangium produces four tetraspores. The tetraspores in turn develop into sexual plants.

The life history is much simpler at the Dry Tortugas, where the only kind of plant found is non-sexual. On these are borne sporangia as usual, but instead of producing tetraspores the sporangium behaves as a monospore, and germinates directly, while still attached to the mother plant, to form a sporeling up to 2 mm. long. These sporelings often occur in such numbers as to render the whole plant bristly. They do not mature while attached to the mother plant but fall off by abscission and then become attached by the basal end to some suitable support.

Sporelings were sown on concrete blocks. After they became firmly attached, the blocks were placed in 7 feet of water west of the Laboratory. Here the sporelings grew normally and produced tetrasporangia, thus completing a full generation from spore to spore without the intervention of sexual reproduction.

Material was preserved for a cytological study of nuclear behavior in vegetative cells and tetrasporangia, and of the abscission phenomena.

A second project was the study of certain very simple members of the Phæophyceæ not hitherto described. Two of these were selected for inten-

sive examination. It is believed that the description of these forms will throw some light on the evolution of the Brown Algæ.

In one of these forms the vegetative body is a colony of stalked cells which, while not possessing flagella, nevertheless resemble Flagellates in some important particulars. Reproduction, on the other hand, indicates clearly Phæophyceean affinities.

In the other form a filamentous branching habit of growth is associated with an extremely simple type of reproduction of a type not found in the better developed members of the Brown Algæ.

A third problem concerned the identity of a species of *Aglaozonia* listed in Dr. Taylor's monograph. This closely resembles a species of *Zonaria*. The two genera mentioned belong to different orders, and there are reasons for doubting whether *Aglaozonia* is found on the American coast at all, although it is listed for the West Indies, and the Tortugas plant is no doubt the same. Material was preserved for a careful examination to determine if possible whether the order Cutleriales is really represented (by *Aglaozonia*) in American waters.

Comparative Study of Fish Blood, by Warren H. Lewis

The uncertainty regarding the origins and relationships of the various types of blood-cells in vertebrates has led me to attack the problem through a comprehensive comparative study of blood-cells of fish and other vertebrates. The fish are of special interest because they lack bone marrow, which in the higher vertebrates is apparently the location of the maturation of several types of cells. During my visit at the Tortugas Laboratory preparations (smears stained by the Wright method) were obtained of blood from 52 species of the subclass Teleostomi, representing 43 genera, 30 families, 16 sub-orders and 9 orders. Blood smears from 20 more species representing 12 additional families, 4 additional orders and 1 additional subclass (Selachii) were obtained later in the summer at the Mount Desert Island Biological Laboratory. Preparations were also made there from hag-fish, which represents a still more primitive type of vertebrate without either bone marrow or spleen, and from representatives of amphibia and reptiles. Tissues were also obtained for the study of the genesis of the blood-cells.

Blood cultures from 13 species were studied at the Tortugas Laboratory to determine if possible the transformation of monocytes into macrophages and of lymphocytes into monocytes and macrophages. The cultures amply supported our previous observations on the transformation of monocytes into macrophages and epithelioid cells, but left uncertain the question as to whether lymphocytes were transformed into monocytes.

With the blood smears as the basis, I am comparing the blood-cell pictures of the various species, families and orders, with one another to determine first of all how they compare with the present classification of the class Pisces, which is based to a great extent on such morphological characters as form, size, skeleton, jaws, teeth, gills, scales, fins, tail, eggs, color and so forth. The preliminary examination of some of the preparations

indicates that the blood-cells of the various species, families and orders of the Teleostomi vary much less than the above characters, and while there are many minor differences, even in the same order in regard to the relative proportion of the various blood-cells, it may not be possible to distinguish the families, or even the orders by the blood-cell picture. There is, however, a very marked difference between the blood-cells of the sub-class Teleostomi and the sub-class Selachii.

The red blood-cells of the Teleosts are small and nucleated. They vary somewhat in size and form and in the size and character of the nuclei. Some of the preparations show numerous maturation stages from a lymphoid-like cell to the mature red blood-cells. The red blood-cells of the Selachians are very large and the number of the maturation stages much more pronounced than in the Teleosts.

Most of the Teleosts have at least 5 types of white blood-cells, namely, spindle cells (thrombocytes), lymphocytes, neutrophiles, eosinophiles and monocytes. They are all small and the relative number of the different types vary considerably in the different fish. The spindle cells and lymphocytes are fairly abundant in all the orders so far studied. The spindle cells are especially abundant in the Pediculati and the lymphocytes in the order Apodes. The neutrophiles are common in all the orders except the Plectognathi. They usually have an oval nucleus, and only rarely is there a slight lobulation. Monocytes are present in small numbers in all the orders so far examined. The eosinophiles are especially abundant in Pediculati and slightly less so in the order Apodes. They are rare in most of the other orders. The eosinophiles usually have an oval nucleus. Occasionally in some species there is a slight lobulation. Basophiles are very rare; an occasional one was observed in the order Iniomi.

Studies on Marine Trematode Life Histories, by O. R. McCoy

Although a number of life histories of fresh-water trematodes have been worked out, there is very little knowledge regarding the life cycles of marine forms. Lebour (1912; 1914) made observations upon certain British marine cercariæ and metacercariæ and their probable relations to the adult trematodes of the region; and Tennent (1906) traced the life history of *Bucephalus haimeanus*. These two investigations comprise practically all that is known of marine trematode life histories.

The trematode fauna of Tortugas was first studied by Linton, who described more than 60 species of adult trematodes from the fishes and turtles (Carnegie Inst. Wash. Pub. No. 133), and Pratt (1911; 1914) has reported several additional species. The larval forms of the region are known through a survey of the mollusks made by Miller (Year Books, Nos. 24 and 25) who found 19 species of cercariæ. With this knowledge of the adult and larval forms as a foundation, it was the purpose of this investigation to attempt to work out some of the life histories experimentally. The writer is greatly indebted to Dr. W. H. Longley for the identification of the fishes used in the experiments, and also for many valuable suggestions regarding their food habits.

The first part of the investigation consisted in making a survey of Bird Key Reef to discover the cercariæ, metacercariæ, and adult trematodes most commonly present. Cercariæ were obtained solely from *Astræa americana* Gmel. and *Cerithium litteratum* Born, the two most easily collectable snails on the reef. The eight species of cercariæ described from these snails by Miller were found again by the writer, and in addition two new species were found in *Cerithium litteratum*. These new species will be designated as Cercaria R and Cercaria S, continuing the lettering used by Miller for Tortugas cercariæ, and a brief description of their morphology will be appended to this report to keep the list of known larvæ complete. Cercariæ A, E, F and P could be obtained in abundance, and with the exception of Cercaria Q, which was found on only one occasion, infestations of all the other species were found at least several times. About 50 fish representing 20 of the commonest species frequenting the reef were examined for adult trematodes. Nearly every fish examined harbored at least one species of trematode, and most of the species found could be identified as forms described by Linton or as closely related species. Probably nearly one-half of the fish trematodes of Tortugas, however, are still undescribed, many of these undescribed forms occurring in the small reef fishes, only a few of which were examined by Linton.

About 40 specimens of the common green crabs on the reef belonging to the genus *Mithrax* and numbers of the small fish were examined for encysted trematodes. In all, 11 different metacercariæ were found, 3 in the crabs and 8 in the fish. Since the relationships of these forms to neither the cercariæ nor the adults are yet determined, only brief mention will be made of their occurrence. Two encysted gasterostome forms were very common in the small grunts, *Hæmulon* spp., and in the small snappers, *Neomænis* spp., one of them being found in large numbers in the muscles throughout the body of nearly every fish examined. Three of the other metacercariæ found in the small fish were echinostomes, possibly belonging to the genus *Stephanochasmus*. One of these forms, with 29 oral spines in two rows interrupted ventrally, was commonly present in the fin rays of the small snappers. One of the metacercariæ occurring in the crabs most probably belongs in the *Spelotrema* Group of Lebour (1912). The other encysted forms found were all distomes whose systematic relationships were not apparent.

Experiments were performed with all the available species of cercariæ to try to determine the second intermediate host in which they would encyst. Small fish, crabs, annelids and bivalves were exposed to the cercariæ and then subsequently examined for cysts. All attempts to get the cercariæ to encyst in invertebrates were unsuccessful, but four of the larvæ—Cercariæ A, B and P of Miller and Cercariæ R n. sp.—were found to penetrate small fish to encyst. Feeding experiments carried out with the cysts of Cercaria A demonstrated that they develop in the intestine of the gray snapper, *Neomænis griseus*, into *Hamacreadium mutabile* Linton, 1910, a member of the allocreadine group of trematodes.

The cercaria of *Hamacreadium mutabile* (Cercaria A of Miller) is a cotylicercous distome cercaria from *Astræa americana*, characterized by the

possession of 8 conspicuous stylet glands. This group of "stumpy-tailed" larvæ separated from the microcercous cercariæ by Dollfus (1914) is a well-defined group of marine cercariæ, representatives of which have been described from several widely separated parts of the world. To the writer's best knowledge, heretofore no life history of any member of the group has been definitely known.

In this study, the cercaria of *H. mutabile* was found to encyst in small grunts, snappers, slippery dicks and parrot fish; no other species of fish were exposed. The most prominent changes from the cercaria noticed in the metacercaria are the loss of the tail, the disintegration of the stylet and stylet glands, and the appearance of the digestive tract with prominent ceca extending to the posterior end of the body. Also the excretory vesicle appears dark on account of the presence of concretions. Five nearly full-grown gray snappers were used in the feeding experiments, the fish being killed at intervals of from 2 to 17 days after the feeding of small fish experimentally infested with the cysts. As many as 446 worms were recovered from the intestine and pyloric ceca of these experimentally infested fish; no more than 5 specimens of *H. mutabile* were found as a natural infestation in the 5 control fish examined. Cysts are infective in as short a time as 3 days after the penetration of the cercariæ. The worms grow rapidly after their introduction into their primary host. After a week, they have doubled in size and the testes and cirrus pouch have started to develop. At the end of 17 days, the worms have nearly reached the adult size; the vitellaria are beginning to appear, but the other parts of the female reproductive system are not yet developed. The laboratory closed before there was time to obtain sexually mature specimens experimentally.

Cercaria B is a cotylicercous cercaria also from *Astræa americana* and very similar to the cercaria of *Hamacreadium mutabile*, except that it contains 14 stylet glands instead of 8. Mature cercariæ were found in small numbers on only a few occasions. This species also penetrates small fish to encyst. One gray snapper was fed two small fish lightly infested in the laboratory with cysts of Cercaria B, and was killed after 2 days. Thirty very small distomes were recovered from the intestine which almost certainly were the young worms developing from the metacercariæ which were fed. A second species of *Hamacreadium*, *H. gulella* Linton, 1910, commonly occurs in the gray snapper, and most probably Cercaria B is the larval form of this species. Since the young specimens found in the experimentally infested gray snapper were too small for positive identification, further feeding experiments are necessary to establish this connection.

No natural occurrence of cysts of Cercaria A or B was found in any of the small fish examined, but the experimental cycle with encystment taking place in small fish is very probably the one that occurs in nature. In any event, the development of a cotylicercous cercaria into a member of the allocreadine group of adult trematodes is established by this study.

Another cercaria found to penetrate fish to encyst was Cercaria P, a binoculate fin-tailed larva with a rudimentary ventral sucker. After encystment the metacercaria undergoes considerable development; a small ventral sucker differentiates, the digestive tract develops, and a single row of 27

large spines appears around the mouth. The presence of this single row of oral spines and the small size of the ventral sucker in comparison with the oral sucker almost certainly fix this larva as belonging to the genus *Acanthochasmus* Looss. It is worthy of note that the cercaria does not show any characters which might indicate its systematic position; all of the distinguishing structures, oral spines, ventral sucker, digestive tract, and even the distinctive Y shape of the excretory vesicle, first appear in the metacercaria. So far as the writer knows, there has been no previous clue as to the type of cercaria to be identified with the genus *Acanthochasmus*.

Cercaria P, which could be obtained in large numbers from *Cerithium litteratum*, was found experimentally to penetrate and encyst in small fish representing 12 genera. The cysts occur almost entirely in the fins and underneath the scales of the fish. One natural occurrence of a cyst was found in the caudal fin of a small snapper. The cercariæ encyst within 12 hours after penetrating the fish, and the cyst wall is thin and transparent. At the end of a week, the body has elongated slightly, the eye spots have begun to disintegrate, and a small ventral sucker has started to develop about the center of the body. The digestive tract, which could not be seen in the cercaria, appears definitely and consists of a long prepharynx, a large pharynx at the level of the eye spots, and a short esophagus dividing into ceca which extend to the posterior end of the body. The excretory vesicle is Y-shaped with the arms reaching nearly to the pharynx. The oral spines begin to develop after 12 days, and by the end of 21 days have attained their maximum size. They are 27 in number and occur in a single uninterrupted circle around the mouth. There are a few smaller spines present on the anterior tip of the body. The body of the metacercaria continues to elongate until it is nearly twice as long as that of the cercaria, and the excretory vesicle becomes slightly dark in appearance on account of the presence of concretions. The eye spots completely disappear after two weeks. The metacercaria apparently attains its complete development three weeks after the penetration of the fish. Small fish experimentally infested with cysts were fed to gray snappers, common grunts and a black grouper, but no adult worms were recovered.

Cercaria R, new species

Large furcocercous cercaria from *Cerithium litteratum* with dorso-ventral fins on furci belonging to the Vivax Group of Sewell. Tail stem about three times as long as body, furci about half length of tail stem. Body covered with very small spines, more numerous anteriorly. Protrusible anterior organ present; small mass of cells in posterior part of body possibly representing rudimentary ventral sucker. Pharynx present, short esophagus branching into conspicuous expanded ceca which extend to posterior end of body. Excretory vesicle consisting of several confluent vessels, the most lateral of which receive collecting tubules; at least 12 flame cells on each side of body. Single excretory canal extending into tail, forking and emptying at tips of furci. Development in large motile elongate sporocysts with anterior end actively protrusible.

Only a few mature cercariæ were available for life-history experiments. A small grunt and small snapper were exposed to some cercariæ, and after 5 days when the grunt was killed, numerous cysts were found in the tissues

throughout the body. The cyst wall was thin, tough and transparent. The metacercaria inside the cyst was a shapeless, structureless mass but still sluggishly motile. A complicated pattern of excretory vessels, dark from the presence of concretions and covering almost the entire body, was the only feature distinguishable. A trace of the anterior organ and pharynx was seen in one flattened specimen freed from the cyst. The further development of this metacercaria could not be followed because of the shortness of time. The second fish, which had to be killed after 8 days, also contained numerous cysts but the metacercariæ showed no appreciable advance in development.

Cercaria S

Small distome cercaria from *Cerithium litteratum* with conspicuous darkly pigmented eye spots. Tail shorter than body and not very powerful. Body covered with small spines and filled with large fat-like globular masses of varying sizes. Ventral sucker slightly smaller than anterior sucker. Pharynx present; remainder of digestive tract not seen. Excretory vesicle in posterior end of body, thick-walled, and Y shaped. Two pairs of granular gland ducts opening on dorsal lip of mouth; glands not definitely located, possibly dorsal to excretory vesicle. Development in redia with pharynx and short rhabdocœle gut but no locomotor appendages. Cercariæ react positively to light.

Observations on Certain Littoral and Terrestrial Animals at Tortugas, with special reference to Migrations from Marine to Terrestrial Habitats, by Arthur Sperry Pearse

Certain reef, beach and land animals were studied. Hermit crabs which have become more or less adjusted to land life show a progressive reduction in the number of gills, and *Cenobita diogenes* lives after all its gills have been removed. Crabs which have migrated landward show a progressive lessening of gill-volume in relation to body-volume. *Ocypoda albicans* has lost a third of its gills and has developed branchial tufts on the lining of its respiratory cavity.

Beach animals which show any landward trend usually live longer in air than in fresh water. Animals which have attained some degree of ability to live on land have also often acquired a greater degree of ability to resist the extraction of constituents of body-fluids into fresh water. Thus their external membranes tend to maintain stability within their bodies. Animals which migrate from the sea and become established on land do not do so on account of one "lure," or one "danger." Each habitat has certain advantages and certain disadvantages. A continually changing animal must continually make adjustments to a continually changing environment and, when it migrates to a new habitat, must make many compromises between new advantages and dangers, old necessities and new requirements, and old habits and new abilities.

Cenobita and *Gecarcinus* live continuously on land, except for a brief annual pilgrimage to the sea, where homage is paid to ancestral custom by leaving young crabs to spend a few days in the ocean. Both these are afflicted with parasitic mites in their gill chambers, but *Ocypoda*, which bathes frequently in the ocean, lacks such parasites. An ideal land animal is air-breathing, water-conserving, swift and internally stable.

Spiral Movement of Leucocytes of the Common Conch, Strombus gigas,
by Asa A. Schaeffer, University of Kansas, Lawrence, Kansas

Leucocytes from a number of crustaceans and molluscs and from a few echinoderms were examined in the hope of finding a rapidly and uniformly moving leucocyte for experimental tests on spiral movement. No entirely satisfactory one was found, most of them being incapable of uniform locomotion except for short periods of time. A small percentage of the "granulocytes" of the common conch *Strombus gigas*, was found to move for longer periods of time and more uniformly than any other, from all the animals examined. But these frequently became almost motionless for periods up to an hour or even more, after which they started moving again.

To test their capacity for moving spirally, from one to about six granulocytes, with normal plasma, were sucked into small glass or quartz tubes with an internal diameter of from 2.5 to about 8 times the length or width of the granulocyte. The path was plotted by means of a camera lucida at regular intervals. The shape in active movement is oval, with the broad side advancing. The average width is about 12μ and the rate of movement may be as high as 30μ at 33° C. for short periods of 10 to 30 minutes. No complete regular spiral turns around the tube were observed, though the longest stretches of most rapid and uniform movement were made at an angle of about 30° to the long axis of the tube, which corresponds with results obtained from several species of amebas under similar conditions.

But a new feature of spiral movement came to light in these granulocytes which may prove to be of great interest theoretically in considering the mechanism underlying spiral movement. It was observed that after a short period of rapid movement in a comparatively straight path, the rate of locomotion slowed down and coincidentally the path began to curve to form a clock-spring spiral from 1.5 to 4 times the diameter of the granulocyte. From 0.5 to 2 turns were made before the granulocyte became quiet or too irregular in its movements to be considered ordered locomotion. These spiral paths in two dimensions therefore resemble those of other animals confined to move in two directions of space, such as mice and men, when blindfolded. No cause could be determined for the frequent slowing down of the granulocytes.

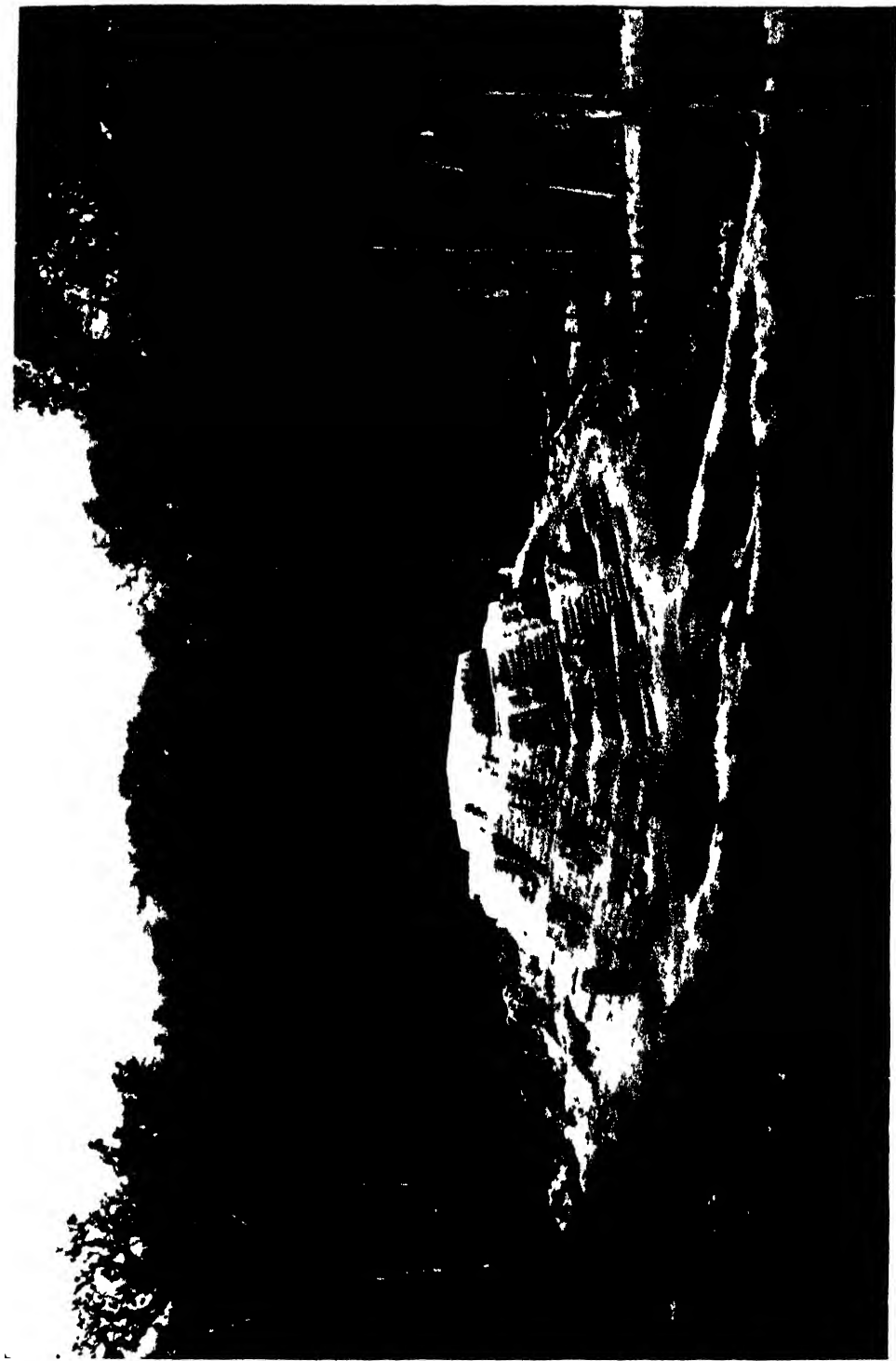
The movement of these and other granulocytes is frequently referred to in literature as "ameboid," but as a matter of fact it is much more like that of a foraminiferan like *Gromia*, with a small number of pseudopods, than like that of any ameba. The clear "lymphocytes" of *Strombus* are much smaller than the granulocytes and their movements are slight and irregular, and can hardly be called locomotion.

I also made a special effort to test the effect of a magnetic field on the movements of the granulocytes but failed to secure definite results, chiefly because a uniform rate of movement is not normally maintained for a long enough period of time to permit of several successive alternations of open and magnetic fields. This test is of considerable importance, since an apparently marked positive magnetic effect in accelerating the rate of movement was brought to light in a series of experiments on an ameba (*Rugipes bilzi*) during the past year. It would be of importance to know whether a similar effect is produced in other forms of streaming protoplasm.

*Further Study of the Control of Regeneration in Pennaria by
Thyroxin, by Harry Beal Torrey*

During the present season studies begun in 1927 on the effect of thyroxin on the regeneration of the hydroid *Pennaria tiarella* have been continued, with results that confirm in essential respects the preliminary conclusions of last year. Thyroxin retards the regenerative development of the hydranth in *Pennaria*, just as it retards the fission rate of *Paramecium*, and the rate of cleavage of sea-urchin and ascidian eggs as well as the differentiation of their larvæ. In solutions comparable in iodine content with the solutions of thyroxin used, metallic iodine is a more potent inhibitor than the latter. Potassium iodide, similarly used, is on the other hand less potent.

The technique briefly described in Year Book 26 was employed, with some slight variations. The regenerating stems were supported on narrow strips of glass designed to keep them away from the bottom of the dishes and minimize the tendency of all types of young buds in *Pennaria* to differentiate readily into holdfasts when in contact with the substratum. Thyroxin was used in concentrations varying from 1:50,000 to 1:600,000. In the lower dilutions—1:50,000, 1:66,000, and occasionally 1:100,000—precipitation was observed, involving the thyroxin, to judge by the diminished physiological potency of the solutions in which it occurred. This precipitate did not form in distilled water nor in van't Hoff's solution. It appeared to be connected with the presence of organic substances in solution in the sea-water employed, and recalled similar precipitation in cultures of *Paramecium* (J. G. Physiol., VII, 449) containing thyroxin in a 1:10,000 concentration.



PYRAMID E-VII SUB AT UXAKTUN PETEN GUATEMALA, AFTER EXCAVATION

ARCHÆOLOGY

Morley, Sylvanus G., Santa Fe, New Mexico. Associate in American Archæology. (For previous reports see Year Books Nos. 13-26.)

There were two principal investigations in Middle American Archæological Research in 1928 as follows:

1. The Chichen Itzá Project.
2. The Uaxactun Project.

Two subsidiary expeditions were also made—one from Chichen Itzá, Yucatan, Mexico, and the other from Belize, British Honduras:

3. The Ek Balam Expedition.
4. The Pusilhá Expedition.

The Chichen Itzá Project completed its fifth field season on June 2 with the conclusion of excavation and repairs at the Temple of the Warriors.

The staff for 1928 consisted of Sylvanus G. Morley, in charge; Karl Ruppert, administrative assistant; E. H. Morris, archæologist in charge of excavations; P. S. Martin, assistant archæologist; Jean Charlot, Mrs. E. H. Morris and Lowell Houser, artists; Thomas R. Johnson, surveyor and draftsman; Miss Katheryn MacKay, housekeeper and trained nurse; Miss N. E. Piatt, secretary and bookkeeper; Gustav Stromsvik, carpenter; and Ira Guillot, mechanic.

On December 26, Dr. Morley delivered a lecture entitled "Recent Excavations of the Carnegie Institution of Washington at Chichen Itzá, Yucatan, and at Uaxactun in Guatemala," at the opening General Session of the American Association for the Advancement of Science at Nashville, Tennessee, in place of Dr. L. H. Bailey, the retiring President, who was prevented by illness from giving the customary principal address; and on January 6, another lecture, at Mexico City, entitled "The Excavations of the Carnegie Institution of Washington in 1927 at Chichen Itzá, the Holy City of the Mayas," under the auspices of Dr. J. M. Puig y Casauranc, the Minister of Public Education.

Mr. Morris with most of the other staff members reached Yucatan on January 3 by way of New Orleans, and work at the Temple of the Warriors was resumed on January 11.

Excavations at Chichen Itzá during the 1928 field season were carried on at two centers: The Group of the Thousand Columns and the Temple of the Two Lintels at Old Chichen Itzá; work being done at five stations as follows:

- Temple of the Warriors (Station 4).
- The Northwest Colonnade (Station 10).
- The North Colonnade (Station 8).
- The West Colonnade (Station 9).
- Temple of the Two Lintels (Station 7), Old Chichen Itzá.

Again, as in 1927, the principal center of investigation at Chichen Itzá was the Temple of the Warriors and contiguous structures, the North, West,

and Northwest Colonnades. The current year witnessed the completion of excavation and repair work at the Temple of the Warriors, and the preparation of the final report thereupon. Special reports covering different phases of this work by E. H. Morris, Jean Charlot and Mrs. Morris will be found on pages 297, 300, and 297, respectively.

Easily the outstanding event of the year at Chichen Itzá was the discovery on March 6 by E. H. Morris, of a turquoise mosaic disk in a sealed stone urn, buried beneath the floor of the sanctuary of the Temple of the Chac Mool, the earlier temple enclosed by and incorporated in the pyramid supporting the later Temple of the Warriors. This is probably the most important single object ever found *in situ* in the Maya area.

This magnificent specimen, 8.75 inches in diameter and comprising more than 3,000 pieces of cut and polished turquoise, was unfortunately in very poor condition when found, owing to the decay of the wooden plaque to which the elements of the mosaic had been fastened, and highly skilled technical attention was immediately necessary if it were to be preserved. The President of the Institution recommended to the Executive Committee an additional allotment to meet this emergency, and through the cooperation of Dr. Clark Wissler, Curator of the Department of Anthropology at the American Museum of Natural History, New York City, the services of Mr. Schouchi Ichikawa, the Museum's most skilled preparator, were secured. Mr. Ichikawa reached Chichen Itzá on April 12 and, in addition to resetting the mosaic on a new base, he painted a water color reproduction of it for use in the forthcoming report upon the Temple of the Warriors. He returned to New York on June 11. For a description of the discovery of this disk see E. H. Morris' report on page 297.

The President of the Institution and Dr. A. V. Kidder, Associate in charge of investigations in Early American History, visited Chichen Itzá from March 1 to 12.

On March 10 exercises were held at the Temple of the Warriors marking a stage in the development of the Institution's archæological program at Chichen Itzá. A special train from Merida brought the Governor, Dr. Alvaro Torre Diaz, General Federico Verlanga, Chief of Military Operations in the State of Yucatan, and other prominent officials. There were addresses by Dr. Merriam, Governor Torre Diaz, Mr. Eduardo Martinez Cantón, Inspector of Archæological Monuments for the State of Yucatan, who had been designated the special representative of the Department of Archæology, of the Ministry of Public Education for the occasion, and Dr. Morley. A luncheon was served to 60 invited guests on the corridor of the *Casa Principal*, and the day closed with a *baile regional*, or native dance, in which some 200 Maya Indians and Yucatecans from the neighboring villages of Pisté, Xocenpich and Dzitas took part.

Before leaving Yucatan, Dr. Merriam, accompanied by Mr. José Reygadas Vertiz, the Director of Archæology, Messrs. Eduardo Noguera and Eduardo Martinez Cantón of the Department of Archæology, Dr. Kidder and Dr. Morley, visited Uxmal, where the Mexican Government has been carrying on urgently needed repairs at the House of the Governor.

On March 15, Doctors Merriam, Kidder and Morley left Progreso for Mexico City, where several days were passed in conferences with the Minister of Public Education, and other officials.

The practically complete restoration of the Temple of the Two Lintels at Old Chichen Itzá under the direction of Paul Martin was brought to a successful termination on April 28. The excavation and repair of this structure was commenced last year, and its esthetic as well as scientific importance¹ indicated the advisability of complete restoration. Although the roof and most of the exterior walls had collapsed, practically all of the building stones were either lying where they had fallen, or were found built into later dry-laid walls in the immediate vicinity. A single section of the rear façade was standing to within two courses of its original height, and furnished the pattern for the arrangement of the elements of the design. The combination of these several factors made possible practically a complete restoration of this beautiful example of Maya architecture, even to the reconstruction of the corbel arched roof, the first attempt of this kind ever made. While the cost in time of technical supervision, as well as in money, and the comparative scarcity of architectural units, where complete restoration may be carried out with such a high degree of accuracy, render it inadvisable, as indeed it is unnecessary, to do much work of this kind; nevertheless, the various operations involved in rebuilding this temple from the ground up, and the replacement of the decorative elements in their original positions in the façades have shed much light on ancient Maya architectural practices. For a description of this work see Paul Martin's report on page 302.

In addition to these more intensive investigations, involving excavation and repair, it has been thought advisable to carry on simultaneously further exploration of the outlying sections of Chichen Itzá, which stretch in some directions, particularly to the southeast, south and southwest, for several miles beyond the religious and civic center of the city. This work has been in charge of Karl Ruppert and has had most gratifying results. At least twelve groups of major importance were discovered, distant from half a mile to 2 miles from the center of the city, several containing hitherto unknown types of buildings. The most important single construction found was a walled enclosure, 50 feet square. The wall surrounding this, although much demolished, had originally stood about 8 feet high, and was 4.25 feet in thickness. The enclosure has never been roofed and the only entrance is a doorway, 8 feet wide, in the middle of the north side. This doorway had had its jambs carved with panels of hieroglyphs, 3 columns of 9 glyphs each—27 in each panel, or 54 in all. Notwithstanding the fact that all these glyphs are practically in perfect condition, no calendric or chronological signs have been identified, and it has been impossible to date this interesting construction.

An extension of this exploratory work, specifically as applied to securing approximate ground-plans of structures without excavation, other than a few pits to expose a wall or develop a corner, has led to most satisfactory results. The Market Place, an imposing construction, 245 feet long and 22 feet in depth, occupying the entire south side of the Court of the Columns,

¹ See Year Book No. 26, pp. 233-238.

has been fairly accurately measured and plans have been laid for its excavation and repair. It was a matter of surprise that such accurate ground-plans could be secured without extensive excavations, and application of this technique to other structures is recommended. Indeed further exploration of the outlying sections of the city must be made. As yet no single construction of the first period of the city's history, 531 to 669 A.D., has been identified, the single dated object therefrom being the re-used door lintel in the Temple of the Initial Series at Old Chichen Itzá. Perhaps a dozen buildings are surely referable, on stylistic grounds, as well as because of the dates actually inscribed upon their door lintels, to the second period, 965 to 1191 A.D. While there are literally several hundred constructions—temples, colonnades, ball-courts, domiciliary buildings, quadrangles, towers, platforms, causeways, etc., which may be ascribed to the third and closing period, 1191 to 1445 A.D., until now, not a single building has been found which is surely referable to the earliest period. Exploration should be extended even beyond the limits of the city, as far as Yaxuná¹ for example, and even farther if necessary, in order to locate if possible the earliest Chichen Itzá and establish the site of the original city of this name. For Karl Ruppert's report on this exploration work see page 305.

A fourth activity at Chichen Itzá during the current season has been Miss MacKay's clinical work among the Maya Indians of the region. Free weekly clinics have been held, not only at Chichen Itzá but also at the neighboring villages of Pisté and Xocenpich, from which the labor of the Project is almost exclusively derived. These clinics were well attended. Simple talks on sanitation, and on the extermination of flies and mosquitoes were given, and the natives eagerly absorbed the information imparted. Miss MacKay finds the commonest illnesses from which the Maya of the region suffer are malaria—present rather in chronic than malignant form—intestinal and digestinal disorders, colds, anemia and malnutrition. A continuous diet of corn, beans, salt pork, very little fresh meat and practically no green vegetables, probably causes most of their maladies, and malaria and its sequelæ are responsible for the rest. Bad colds and catarrhal affections are common and develop frequently into bronchial pneumonia and pleurisy, running extremely high temperatures, but in spite of this susceptibility to infections of the respiratory system there is almost no tuberculosis. The number of cases examined at the staff quarters during the current season was in the neighborhood of 250, many walking more than 25 miles for treatment. Some 130 cases were treated at the clinics in outside villages, and 18 cases at the Mexican Government quarters at Chichen Itzá, a total of about 400.

On March 25, Dr. Kidder and Dr. Morley and Dr. G. C. Vaillant of the American Museum of Natural History left Mexico City for Guatemala City. During the course of a fortnight's stay in Guatemala, Dr. Kidder and Dr. Vaillant visited some sites near Lake Atitlan, in company with Dr. S. K. Lothrop of the Museum of the American Indian, Heye Foundation; and later spent two days with Dr. Morley at Quirigua. In Guatemala City

¹Yaxuná is located about 15 miles south and slightly west of Chichen Itzá, and is the western terminus of the Cobá-Yaxuná *sacbe* or highway. See Year Book No. 26, p. 239.

several calls were made upon Mr. J. A. Villacorta C., Minister of Public Education, and the Institution's program of archæological investigations in the Middle American field was considered with him. On March 30 Dr. Morley gave a lecture in Spanish before the Society of Geography and History of Guatemala, of which he is an Honorary Member, on the work of the Institution both at Chichen Itzá and at Uaxactun. On April 13, Doctors Kidder, Morley and Vaillant left Puerto Barrios, Guatemala, for Belize, British Honduras; and on April 15, Mr. Amsden, in charge of the Uaxactun Project, met them at Belize and took them up the Belize River to the head of navigation, and thence by mule-train to Uaxactun, 50 miles westward in the northern central part of the Department of Peten, Guatemala.

The most important contribution at Uaxactun during the current season was the excavation of Pyramid E-VII, the key structure of the astronomically significant Group E. The discovery of a stucco mask buried under an outer covering of rough masonry and crumbling plaster was reported last year,¹ and during the present season three-fourths of this later and much cruder outer layer was removed, the remaining quarter, the southwest corner, being left as found for a control section. There stood revealed what is unquestionably one of the finest examples of ancient American architecture extant (see the accompanying plate)—a terraced pyramid with stairways on all four sides, two pairs of great stucco masks flanking each stairway. The summit had never supported a masonry superstructure, as the original and unbroken plaster floor clearly shows.

This buried pyramid must have been constructed at a very early date. Dr. Vaillant's excavations in the floor of the plaza of Group E, and around the foundations of Stelæ 18, 19 and 20, the first two of which date from 97 A.D., clearly show that these monuments were erected subsequent to the latest floor level, which was in turn associated with the rough masonry covering, which had been built around Pyramid E-VII. See page 313 for Dr. Vaillant's report on these excavations.

Stylistically considered, this stucco-covered pyramid is pre-Mayan. Its decorative motives are like nothing else known in the Old Empire region. They have a flavor of the Archaic, without being of the Archaic. Esthetically they are pre-Maya, but not necessarily un-Mayan. At the very early date when this pyramid was constructed, probably well before the beginning of Baktun 9, it is strongly to be doubted that Maya art and architecture had developed the essential qualities which became so diagnostically characteristic of it in later Old Empire times.

Dr. Vaillant's excavations in the plaza of Group E satisfactorily substantiate the indications afforded by the stylistic evidence. He found three earlier plastered floor levels below the last floor level, and eight feet of débris between this last floor and the undisturbed humus soil. This débris was filled with potsherds, ash and small anthropomorphic figurines of baked clay, including two whistles, one modeled like the head of a man, the other like a bat. Some of these clay figurines strongly resemble similar Archaic figurines from the highlands of Guatemala and, without being identical,

¹ See Year Book No. 26, pp. 257, 258.

suggest some as yet undetermined relationship therewith, possibly not remote. Indeed the scientific importance of the results at Uaxactun this season lies in the possibility that the stratified meeting-ground of the Archaic and Maya cultures, so long sought, may at last have been found in this very group.

Aside from its indubitable scientific significance, which may have a fundamental bearing on the relative ages of the Archaic and Maya horizons, Pyramid E-VII is, esthetically considered, scarcely of less importance. Buried beneath a subsequent construction at a very early date, it has been preserved for us, 98 per cent as it was 18 or more centuries ago. Of extraordinarily satisfying proportions and harmonious silhouette, this pyramid rises in dazzling silver-white brilliance against the somber green background of the Peten forest and the vivid cloud-flecked blue of the Peten skies, an architectural masterpiece of rare beauty. For O. G. Ricketson's report on the Uaxactun Project see page 307.

While at Uaxactun, Dr. Morley visited Tikal for the purpose of examining the plain stelæ in the northern part of the city. Opportunity was also taken to check his new reading of Stela 18, i.e. 8.19.0.0.0. Stylistically considered, Stela 18 is the earliest monument at Tikal, indeed its only other stylistic analogues known anywhere being Stelæ 9, 18 and 19 at Uaxactun, and Stela 1 at Uolantun, all dating from before the beginning of Baktun 9. The inscription unfortunately is not only fragmentary but also extremely weathered; the uinal and kin coefficients appear to be 0, and the day of the Initial Series terminal date is pretty surely 10 Ahau. If the tun coefficient is also 0, as is probable, then the only reading within the limits fixed by the stylistic criteria is 8.19.0.0.0 10 Ahau 13 Kayab. A new plain stela (D8) and a beautifully sculptured altar (No. VII) accompanying it were found in front of the stairway leading to Temple III; another plain stela (D9) was found 100 yards north of the northwest corner of the pyramid supporting Temple III.

Dr. Kidder and Dr. Morley returned to Belize on April 30, and the former returned to the United States on May 5. On May 2, Dr. Morley left Belize for Punta Gorda to visit a site named Pusilhá in southern British Honduras, about a mile east of the western boundary of the Colony. For a report of the Pusilhá Expedition see page 318. Dr. Morley left Belize on May 12 and reached Chichen Itzá again on May 24, after an absence of two and a half months.

Mr. Martin returned to the United States on May 9, Mr. Ichikawa on June 11, Mr. and Mrs. Morris and Miss Piatt on June 12, Messrs. Stromsvik and Houser on June 14, Miss MacKay to Mexico City on June 1, and Mr. Charlot to Mexico City on June 16.

At the invitation of the Rotary Club of Merida, Dr. Morley gave an illustrated lecture in Spanish at the Peón Contreras Theatre in Merida on the evening of July 3, describing the results of the 1928 field season at Uaxactun and at Chichen Itzá. The turquoise mosaic disk was on exhibition in the foyer of the theatre after the lecture and also at the newly inaugurated Casa del Pueblo, or People's House, during the evening of July 2. Dr. Morley left for Mexico City on July 4.

On July 7, Dr. Morley delivered to Professor Moise Saenz, the Under-Secretary of Public Education, the turquoise mosaic disk, the stone urn in which it was found, and the associated material—a carved jadeite pendant, two jadeite beads and a conjuring stone of the same material.¹

At the invitation of Dr. Alfredo Pruneda, Rector of the University of Mexico, Dr. Morley gave three lectures before the Summer School of the University as follows:

July 9. Origin of the Maya Civilization and the Old Maya Empire.

July 11. Decline of the Maya Civilization and the New Maya Empire.

July 13. Maya Hieroglyphic Writing.

He returned to the United States on July 14.

The appointment of Mr. Ruppert as administrative assistant of the Chichen Itzá Project has relieved Dr. Morley of the routine of administration at Chichen Itzá, and his time has been devoted to the preparation of his report on the "Inscriptions of Peten." As originally contemplated in 1914, this work was to have contained "descriptions and decipherments of all known Maya texts, which will be so arranged as to be a ready and standard book of reference on Maya chronology."² It soon became apparent, however, that further field work would be necessary before such a book could be written,³ and as early as 1915 so many texts had been transcribed at Copan alone,⁴ that it was decided to bring out the Copan texts in a volume by themselves. The World War intervened just as the first chapter of this book had gone to press,⁵ and the first volume of this work (Publication No. 219) was not published until the spring of 1920.⁶

During Dr. Morley's seven trips to the Department of Peten in 1914, 1915, 1916, 1920, 1921, 1922, and 1928⁷ he has collected material for the second volume of this work on the Maya inscriptions, to be entitled *The Inscriptions of Peten*, and he is now engaged upon its preparation.

Report of Earl H. Morris on the Excavation and Repair of the Temple of the Warriors (Station 4)

During the field season of 1928, activities at the Temple of the Warriors consisted principally of explorations within the pyramid. Until after the end of the 1927 season, it was the plan to leave unreplaced a slot in the northern face of the pyramid for the purpose of revealing a portion of the substructure of the buried temple (Temple of the Chac Mool), and to provide an entrance to the latter structure. Eventually it was decided to close this slot, and to provide access to the under temple from the terrace at the north side of the Temple of the Warriors.

¹When this ball of jadeite was first shown to the Maya laborers, they unanimously identified it as a *sastun* or conjuring stone, which the ancient Maya priests are said to have used in making incantations.

²See Year Book No. 13, p. 333.

³See Year Book No. 14, p. 343.

⁴See Year Book No. 15, p. 337.

⁵See Year Book No. 16, p. 287.

⁶See Year Book No. 19, p. 321.

⁷See Year Books No. 14, pp. 343-346, No. 15, pp. 337-341; No. 19, pp. 321-324; No. 20, pp. 359-368; and No. 21, pp. 310-319.

In order to make this new entrance, it was necessary to remove a cube of ancient rubble extending 17.5 feet eastward from the back wall of the buried temple and from the existing slope of the pyramid southward to the vertical line of the base of the wall of the Temple of the Warriors. This mass was removed in layers of from 3 to 5 feet in thickness, depending upon the solidity of the rubble at the particular moment. After each such layer had been removed, the rubble directly beneath the wall of the Temple of the Warriors was picked clean of small stones and mortar and brought to a vertical face with chinking and masonry of cement. After this procedure had been followed to a depth of 17 feet 3 inches, or to the floor level of the buried temple, a 1.5-foot wall of lime-bonded masonry was built along the south side as an additional reinforcement beneath the foundation of the Temple of the Warriors. At the same time the east side of the pit was walled, the masonry resting on a flat arch buttressed against the shell of the pyramid and the end of the south pit wall.

A reinforced concrete girder was cast at the level of the top of the second sculptured band of the pyramid to support the shell thereof, thence upward. Upon this the shell was raised with vertical inner face, and a thickness at the base of 4 feet, to the floor level of the buried temple. Thence upward, for 8 feet 3 inches, was constructed a three-sided Maya vault open on the south, for the purpose of lessening the thickness of the shell and leaving visible more of the earlier substructure beneath this arch. The north side of the arch forming its inner face, the pyramid shell, was carried up to the height of the arch cap, then continued vertically upward to the full height of the pyramid. In the fourth vertical element were set three windows like those left last year in the same panel for giving light and ventilation to the buried temple.

The pit was roofed with concrete in the same way that the under temple had been covered in 1927. A stair well was left in this roof adjacent to the wall of the Temple of the Warriors, and extending eastward beyond the eastern side of the pit. Leading down through it and on across the pit to the rear terrace of the buried substructure, was built a reinforced concrete stairway.

While the upper half of the pyramid shell, the roof and stairway, were being built, the pit was continued downward. The rubble was removed in levels of from 3 to 5 feet in thickness, depending upon its solidity or relative looseness, and the débris carted out to the north beneath the previously mentioned concrete girder. After each level was dug away, the rubble beneath the upper walls was removed and replaced with cement-laid masonry. This process was repeated until the pit reached a depth of 34 feet 3 inches below the summit of the substructure supporting the Temple of the Warriors, its floor being the first terrace of the buried substructure. Then a flat arch was cast from east to west to support the base of the second battered element of the pyramid, and this feature was replaced, as well as the second sculptured band, with the exception of a window left in the latter, 5 feet 7 inches wide, to admit light to the bottom of the pit. Thus there remained a tunnel through the first battered element, to permit of the removal of débris from future excavations within the pyramid.

As the pit was being dug, at the south side, in the line of ancient construction units lying eastward of the third zone of the buried substructure, were found many painted stones torn out of some vertical face and used as common fill material. The majority of these were in a remarkable state of preservation and the painting was excellent, beyond any previously seen in the excavations at Chichen Itzá. Very soon it was possible to begin fitting the blocks together, and it became evident that they were parts of a long panel 32 to 33 inches in height. For some time there was much conjecture where the panel had belonged. Its detached elements occurred in association with many stones known to pertain to the buried temple, but the decoration of the walls as known from portions *in situ* left no place thereon for such a panel. Finally Mrs. Morris established the fact that these elements were parts of two panels instead of one, and that they had been the facing of the two benches which had been torn out of the inner chamber of the buried temple. So great was the desirability of completing them, that a tunnel was driven at the level at which they occurred, 24 feet eastward beyond the pit. It yielded a good many of the coveted stones. When it had been carried beyond the point where they ceased to occur, the bore was filled with masonry and a second tunnel was driven northward of, and parallel to it. This yielded others of these blocks to contribute to a total of 71, of which 38 belong to the south bench and 33 to the north one. These cover about half of the total original area of the two benches. Enough of them could be fitted together to give a complete key to the subject and arrangement of the designs upon both benches. Files of richly garbed priests and warrior figures are represented; and as will be seen from the color reproductions, which will appear in the forthcoming volume upon the Temple of the Warriors group these murals are magnificent almost beyond belief.

After the stair pit had been completed, a tunnel was driven southward along the second zone of the buried substructure of the buried temple. It was dug a few feet at a time, then walled and roofed. The facing of the substructure provided one side, and the other was made of cement masonry to the height of the second zone. The roof consists of a Maya vault, one leg resting upon the cement wall, the other upon the second terrace of the substructure of the buried temple.

While this first tunnel was being constructed another was begun at the western end of the south side of the same substructure. The entry was made at the level of the terrace at the top of the second multiple zone of the pyramid of the Temple of the Warriors. It was driven southward about 10 feet, from the north face of the stair ramp to the end of the third multiple zone which had been included within the mass of the stairway support, then turned to the east a distance of 8 feet, and then to the north for 2 feet to lay bare a portion of the outer face of the south wall of the buried temple.

At the floor level of the east and west portions of this tunnel was found the junction of that part of the back wall of the West Colonnade which had been included within the pyramid of the Temple of the Warriors, and the buried substructure of the Temple of the Chac Mool. To follow this junction downward, a pit was sunk, branching off to the south from the east and

west portion of the tunnel. The roof was brought down at an angle until it rested upon the coping of the wall of the West Colonnade. Beneath that level the first pit was extended southward as a tunnel to a total distance of 16 feet from the substructure of the buried temple. The rubble of the pyramid was loose and prone to cave. In consequence the digging of this tunnel was especially dangerous. Once the upper 5 feet had been completed and roofed, the excavation was continued downward, and the east wall built as the digging progressed. Eventually the level of the first terrace of the buried substructure was reached. This feature, instead of terminating with the width which it bore on the east of the substructure, continued southward as a finely surfaced platform.

From the bottom of the pit a tunnel was started toward the east, following the second zone of the sub-structure. The bore was continued until it met the tunnel being driven along the eastern side at the southeast corner of the base of the substructure of the buried temple. Through this tunnel it is possible to walk along 107 feet of the buried substructure, which, owing to its deep interment in the pyramid of the Temple of the Warriors, is in practically perfect condition. The face consists of four zones. The basal one is a low platform with no embellishment. The second and third have cornices, the space beneath the cornices being divided vertically into alternating jutting and recessed panels. The fourth zone is provided with a cornice like the two beneath, but is without panels. The existing southeast corner is rounded instead of angular. Thus because of the rounded corner and the panelling of the two zones, this substructure bears an extremely close resemblance to the pyramid of the Castillo.

From the southeast corner of the substructure two tunnels were driven, each for a distance of 40 feet, one toward the southeast corner of the pyramid of the Temple of the Warriors, the other toward the southwest. This was for the purpose of determining whether or not there were other structures included in the mass of the pyramid. The tunnel toward the southeast gave an entirely negative result. The other revealed that the first terrace of the substructure of the buried temple continued southward as a platform for a distance of 23 feet 8 inches. There was no indication of a building surmounting this platform.

A careful examination of the floor known to exist from 4 to 10 inches beneath the floor of the Northwest Colonnade established the position of the north wall and anta of the colonnade to which this lower floor pertained, as well as the stubs of two rows of square columns which extended from north to south. A checking of details and levels indicated that this colonnade had borne the same relation to the buried temple (The Temple of the Chac Mool) as the Northwest Colonnade bears to the Temple of the Warriors. A doorway led through the back wall to give access to the platform previously mentioned, situated at the south base of the substructure of the buried temple.

A search for offerings was made in all of the altars that have been uncovered in the vicinity of the Temple of the Warriors. Of the five altars of the solid type, deposits or the proof of their previous existence were found in the three which are known to be parts of the original plans of the build-

ings in which they occur. The two barren ones are of secondary construction. Beneath the Atlantean altar in the Temple of the Warriors no deposit was found. However, deposits true to type occurred under both the northwest and northeast corners of the building itself. As a rule, the imperishable components of the offerings are significant, rather than striking or beautiful. The standard features are sandstone disks, bits of jadeite and shell. However, under the spot once occupied by the Atlantean altar of the buried temple was found an offering of unexpected excellence. The container was a jar hollowed out of a limestone block, and fitted with a stone lid. In the jar lay a turquoise mosaic disk 8.75 inches in diameter. Upon the disk were a jadeite ball, a face and two beads of the same material, together with shell beads from a necklace, and the skeleton of a small bird.

The wooden backing of the disk had entirely decayed, but the film of gum by which the mosaic had been encrusted upon the wood held most of the pieces of turquoise in position, so that the design was preserved. The center of the plaque is a disk of sandstone of the same kind as that found in other offerings. Thus it is evident that this particular quality of sandstone possessed some extremely sacred quality.

Work on the Temple of the Warriors was brought to a close by June 10, marking the completion of the unit of exploration and repair begun early in February 1925. The various structures composing this architectural complex have been freed of débris to the intended limit, all walls laid bare have been repaired and protected to withstand the elements, and such fallen walls as could be replaced with absolute certainty have been rebuilt to the extent that was considered desirable.

In a study of the Temple of the Warriors' complex and definitely related structures, the chronological sequence of seven distinct construction intervals has been established. Fully half of the writer's time during the 1928 field season was spent toward the completion of a monograph upon the Temple of the Warriors.

*Report of Ann Axtell Morris on the Mural Paintings and Painted Reliefs
in the Temple of the Chac Mool*

It was planned at the beginning of the current season to complete the study of those isolated stones, bearing fresco paintings from the Temple of the Warriors, which it had not been possible last year to incorporate into large assembled areas. A number of these had already been copied, but approximately 150 remained, which needed careful revision for the verification of costume and accessory details, as well as for color and technique. In many cases an outline drawing was deemed sufficient record; in others a colored reproduction of the entire stone was considered necessary. When completed, this work included 43 color paintings and 32 outline drawings. The remainder of the stones were found to be of little importance; although they bore traces of color, the designs were too fragmentary to permit their identification.

In addition to this work upon the mural paintings of the Temple of the Warriors, there remained the reproduction of two magnificently sculptured columns, rich with the almost perfect coloring of their original state. These

had been discovered at the close of the 1927 season in the structure buried beneath the Temple of the Warriors, or, as it has been named from the beautiful Chac Mool figure found in its outer chamber, The Temple of the Chac Mool. Later excavations revealed relief after relief which equaled and even surpassed the beauty of this reclining figure, among others being the sculptured columns mentioned. These were copied in water color. In many places on these columns, the relief itself does not coincide with the sometimes carelessly made black outlines with which the painter finished his color work on the relief.

The designs on these columns, which are similar to those on the other columns from this temple, described last year, will be treated in detail by Mr. Charlot, who has made a comparative study of the relief sculpture in the entire composite structure.

Probably one of the greatest and certainly the most gratifying surprise, which the season's work brought to light, was the discovery of 71 painted stones which had been originally incorporated in the face of two benches on the north and south sides of the altar of the inner sanctuary. During the current season it was considered desirable to free the substructure of the Temple of the Chac Mool from its enclosing shell of masonry and it was the section adjacent to the eastern outer wall which produced, so unexpectedly, these beautiful frescoes. When these stones began to appear sporadically, they excited great interest on account of their superb state of preservation, but for a time their provenience was a matter of conjecture. As the work progressed, however, it became evident that they had originally come from the faces of the two aforementioned benches.

These benches were L shaped, the longer axes being built against the north and south walls respectively of the inner chamber and the shorter axes against the north and south ends respectively of the east or back wall, each terminating 8 feet 1 inch from the centrally placed altar. An unpainted white plastered surface remained where this bench had formerly abutted these walls in the south half of the room. The north wall and northern half of the east wall of the Temple of the Chac Mool had been torn completely away in the rebuilding operations coincident with the construction of the Temple of the Warriors, and the dimensions given for the north bench are based upon the assumption of a symmetrical ground-plan with reference to the east and west axis of the temple.

Calculations made from this unpainted silhouette, as it lay against the south wall and the southern half of the east wall, established the fact that the total length of the painted face of each bench had been 25 feet 4 inches and its original height 3 feet 4 inches, the slightly jutting cornice being 7 inches in height. The total height of the assembled stones was within half an inch of the unpainted section on the south and east walls. The design on these benches was found to have been framed with broad blue bands, and splashings of blue paint were found at the point where the bench had formerly joined the black painted wall. The stones from the lower edge of the benches were themselves splashed with red paint from the numerous repaintings of the red floor.

More conclusive proof of the former positions of these stones was derived from a study of the stylistic evidence. Two major groups were immediately noted: (1) pieces executed in a polychrome technique with considerable nicety of detail; and (2) pieces, broadly and crudely treated, done almost exclusively in shades of red. These were found to be parts of the two separate benches—the former belonging to the bench on the right, or south side of the altar, the latter to the bench lying to the left, or north of the altar. The altar was the logical focus of interest in the sanctuary, and the human figures on these benches were found to be orientated so as to continuously face it.

The stones belonging to the south bench, 38 in number, fall into three groups. The human figures of one group when assembled were found to face to the left, and this section coincides with the 14 feet 6 inches required for the face of the bench lying along the south wall. A second group with their figures facing in the opposite direction when fitted together, exactly fill the 4 feet 8 inches of the face of the bench nearest the altar. It seems probable that this reverse facing of the figures of the second group was due to the desire to have them look toward the sanctuary and the front of the altar. A corner stone with incomplete figures facing each other confirmed this hypothesis. The third group, occupying the middle section of the bench, *i. e.*, that lying along the east or back wall of the sanctuary, had been executed by a different hand than the stones lying parallel to the adjacent section of the bench along the south wall, even though its figures faced in the same direction. This stylistic difference made possible a separation of the stones of these two groups, one from the other. Only slightly more than half of the stones were found, although careful search was made for the rest. Their re-use as fill material, mixed with plaster and rubble, had fortunately resulted in but slight damage to the surfaces.

The subject of the painting is a file of human figures seated upon benches covered with jaguar skins. There are warriors panoplied with shields and spears, and priests offering bowls of incense in their extended hands. Sufficient of the design remains to establish the general details of dress and ornament for all the types of human figures represented.

The north bench, as previously stated, was more crudely painted and, in addition, its component stones had suffered rougher treatment in their re-use. Nevertheless, it was possible to identify enough to permit the reconstruction of the design of the entire panel. The human figures, in this case only warriors, are seated upon jaguar stools. The bench along the north wall shows these jaguar stools or seats standing full face to the spectator—head, forelegs and shoulders visible; the tails are drawn in, so that they may be seen between the animal's forelegs. The seated human figures are drawn in profile as are also the jaguars in the remaining two sections of the bench—*i. e.* that lying against the east or back wall and that facing the altar.

Throughout the remainder of the Temple of the Chac Mool, the preliminary outlines are sketched with a flowing red line, but on this bench the outlines of the jaguars were only roughly indicated by scratching them in the wet plaster. These outlines perforce are angular and ugly and very fortunately were not followed in the slightest degree by the artist in his final work. In the upper part of the bench no preliminary outlines were

used at all, the color being applied directly to the plaster in blocked-in masses, which were subsequently outlined with a heavy black line. This unusual technique has been found nowhere else in the city up to the present time.

Both benches show various departures from the usual fresco treatment, the most striking of which are a lavish use of masses of dark paint laid on a red ground, resulting in a rather unique lack of contrast, and the practise of covering the entire surface, preliminary to painting, with a glutinous yellow-white mixture before the subsequent colors were applied. This gives a marked opacity to these particular frescoes, in strong contrast to the clear water-color appearance of the frescoes in the Temple of the Warriors.

A study of dress and ornament has proved of great interest, but lack of space limits even a brief description of these details. The monograph on the Temple of the Warriors, now in course of preparation, will include a comparative study of the subject-matter of the frescoes, as well as detailed analyses of the colors employed, and other problems of technique which have arisen in the course of the work.

*Report of Jean Charlot on the Sculptures of the Temple of the Warriors
and the Temple of the Chac Mool*

As the investigation of no new architectural unit was carried out in 1928, the time of Mr. Charlot and of his assistant, Mr. Houser, was devoted to a completion of work already under way at the Temple of the Warriors and adjoining structures.

Drawings of the sculptures on the columns of the Temple of the Chac Mool, as well as a few left in the Temple of the Warriors, the dais of the North Colonnade and the dais of the Northwest Colonnade were completed this season. The designs on the columns in the Temple of the Chac Mool were described in the Year Book for 1927,¹ but only a few had been drawn at that time.

This season the designs on these columns were copied in line drawings with color notes added in five flat tones, with a view to securing standardization of color reproduction in the lithographic plates. Thirteen drawings with the corresponding color notes were made which, with the seventeen copied in water color by Mrs. Morris, make a complete record of the bas-reliefs that have survived in this temple.

The columns in the Temple of the Warriors had been copied in 1926 in line drawing, independent color notes on transparent paper having been made at the same time. These color notes were transferred this season from the transparent sheets to the drawings themselves, after having been reduced to the five standardized tones adopted for lithographic reproduction.

Another important piece of work concluded during the present season was the painting of the front of the dais in the North Colonnade. The two shorter sides of this dais had been copied in oil in 1927. The front, measuring more than 16 feet in length, was copied this season, also in oil, natural

¹ See Year Book No. 26, p. 248.

size. The two shorter sides of the dais in the Northwest Colonnade had been copied in 1926. Owing to the extensive copying in the field, which has been going on since then, and the technical improvement resulting therefrom, it appeared advisable to retouch the copies of these two sides, painting directly from the corresponding originals.

In addition to the foregoing, Mr. Charlot made drawings as well as water colors of a number of disassociated sculptured units, the original provenience of which is unknown.

Two-color copies were made of the remnants of the beautiful panel composed of flowers and animals found in the fill of the pyramid of the Temple of the Warriors. The sculpture is in rather high relief and presents unknown flowers on graceful sinuous stems ornamented with bud-like leaves. Different insects and birds feed upon them. Although much stylised, the butterflies are still recognizable as such, their wings transformed into two flowing panaches of quetzal-like feathers, the head, with its extended proboscis, retaining many of the original entymological characteristics. Among the birds which could be identified are the crested parrot and the hummingbird, the latter in its characteristic position of sucking the flower while on the wing.

The relief, vividly colored, is in strong contrast to the plain white background. A few stones were found, which are doubtless parts of the same panel although they show no coloring, being done in black and white only. As this duochrome treatment was a preparatory process before color was applied, it is probably to be assumed that this panel, like many sections of the friezes on the pyramid of the Temple of the Warriors, had been completed all but its polychromy, and was then discarded because of some subsequent architectural modification.

The fragments of the serpent-columns belonging to the Temple of the Chac Mool, uncovered in 1926, consist of parts of the two tails and the two heads. The better preserved tail was copied in colors, while a line-drawing was made of the other. Both present, in addition to the usual tail-rattles and feathers, panels consisting of three Atlantean figures each—the figures bearing representations of shells and turtles.

The more important of the two heads, that still having a section of its corresponding columnar shaft, was also copied in color. Its style is strikingly different from that of the similar heads in the Temple of the Warriors. Although the subject matter is the same in each case—the plumed serpent—the treatment, which in the earlier temple is more of an esthetic abstraction, tends in the later Temple of the Warriors to become fairly realistic. The different parts of the serpent's head are represented, but without interfering with, or modifying the primitive squareness of the original block of stone. Here is an interesting stylistic link with some of the sculpture at San Juan Teotihuacan, especially the figure of an ocelot made of alabaster, and a heroic sized goddess in the National Museum at Mexico City.

On the serpent column from the Temple of the Chac Mool, the feathers are painted red; the fangs, of semi-spherical shape, are pink. The outline of the mouth, as well as the scrolls issuing from it, is yellow. The belly

of the snake is yellow and the rattles are blue. A narrow horizontal band of blue and yellow encircles the body at about one-third of its height.

Three line-drawings were made of sections of the three friezes running around the pyramid of the Temple of the Warriors, the examples chosen, illustrating the different elements (men holding ceremonial bars, animals and birds) found on each band. This last work brought out a new fact, showing the ingenuity with which the builders used their wide knowledge of perspective. While on the lowest frieze, which is at the level of a man's eyes standing at the base of the pyramid, the feet of the reclining figures rest directly on the cornice just below them, in the middle and top friezes there is a space left between the feet and the cornices below them. This was done so that, in the diagonal perspective resulting from looking up at these friezes, the feet of the figures would not be hidden by the cornices projecting below them, but appear to rest directly on them. So many and so diverse are the successive layers of paint on these elements, that exact color reproduction would only be misleading. It seems that in the case of the last coat at least, the human figure and its accessories were painted blue, except for the belt, which is green; the eagle is black; the jaguar, yellow; and the unidentified animal which has been called the "woolly" is treated with a hachure of black and white to represent fur. The background everywhere is red.

A copy was also made of the charcoal sketch of an Atlantean figure, found on the unpainted base of the south wall of the sanctuary of the Temple of the Chac Mool, where the bench had formerly stood. This figure is of especial interest, in that it may be the only example of a working drawing for a piece of stone sculpture before execution, which has come down to us. All the field notes necessary for the preparation of a report on the bas-reliefs of the Temple of the Warriors were made, and two-thirds of the text itself was completed before Mr. Charlott left Chichen Itzá. Also, about 200 line-drawings were made, to be used in illustrating the text, in addition to the copy for the full-page illustrations and color plates.

Report of Paul S. Martin on the Temple of the Two Lintels (Station 7)

The repair of the Temple of the Two Lintels was completed on April 28. During the 1927 field season the four exterior walls and the two interior partitions had been reerected to the level of the lowest member of the medial cornice, that is to say, to about half their original height. During the current season, these were completed and the building roofed over.

When work was started on this building in the spring of 1927, it was evident that all the façade above the medial cornice had fallen, with the fortunate exception of a single section of the back wall, which stood to within two courses of the original height. This section served as a pattern for the reconstruction of the entire upper zone, since here, *in situ*, was a complete cross-section (lacking the two courses above mentioned) of the original façade—cornices, inter-cornice element and the decorated panels of the upper zone. There are two types of these decorated panels which alternate with each other clear around the building, the first consists of X-shaped stones, separately cut and fitted together like a mosaic, giving the appear-

ance of lattice-work; the second is composed of four round columns, occupying the same space, both vertically as well as horizontally, as the lattice panels. Since no cut stones were found either in the front or rear, which differed from the elements of the two types of panels, already *in situ*, it seemed safe to assume that the fallen elements should be replaced in the same manner.

The story of the east and west façades is slightly different. The following sculptured elements came to light during the excavation of the two ends of this temple. (1) Five round columns, of the same size as those in the front and rear façades, but banded in the middle with a conventionalized knot, found at the back corners. (2) The several lateral elements of a corner mask found at the front corners. (3) 28 X-shaped stones.

Apparently the upper zones of the ends of the temple were composed of (1) these five special columns, contiguously placed; (2) a solid panel of 28 X-shaped stones, arranged in 4 horizontal rows of 7 X-shaped elements each; and (3) the lateral elements of corner mask panels. From the rear of the temple, only one of these "knotted" columns was visible at each corner.

Justification for this reconstruction of the design is found—first, in the fact that all the sculptured elements exactly fill the space available for them; and, second, the old plaster marks still adhering to the cornice elements corroborate the above arrangement. For a long time, indeed, the positions of these columnar elements were uncertain, but the discovery of the corner stone of the cornice upon which they had formerly rested furnished irrefutable proof of their original arrangement, the ancient plaster marks coinciding to the millimeter with the number of columns actually found.¹

Complete repair of this temple has been possible only because practically all the original material was at hand. For example, only 11 X-shaped stones were missing out of an original total of 264.²

In rebuilding the arches, or corbelled vaults, no temporary forms to sustain them were necessary as in the construction of true arches.

Each vault stone was specially cut so that, when placed in position in the wall, its center of gravity lay well toward its butt so that it could not fall forward; and, to make each stone even more secure, a large rock was placed over the butt, holding it in place until the entire roof was built. A few of the beveled vault stones had to be replaced because some of the originals were too badly weathered and broken to be used again.

The temple proper rests on a platform decorated with sculptured designs; the front has a continuous lattice pattern composed of small separate X-shaped stones, terminating at each end with a mask panel. The platform at the rear consists of alternating panels of small round columns and

¹Throughout the reconstruction of this temple the ancient plaster marks repeatedly served as guides to the former position of doubtful carved elements. They were indispensable in reconstructing the corner masks, and may well be called archæological "divining sticks."

²The interest of the Maya Indian laborers in the reconstruction of this temple was shown by the fact that they volunteered to bring enough similar X-shaped stones, from the village of Pisté, 3 miles distant, to make up this shortage.

a square scroll motive.¹ For some unknown reason this beautiful platform had been covered at some later time in order to raise the whole terrace level upon which the temple stood. In so doing, the long curved noses of the corner masks were broken off and much of the delicate relief, including the animals behind the ear plugs, was covered with a stucco finish.

The lower zone, i. e. the portion of the façade immediately above this beautiful base, is a vertical wall, 6 feet high; it is plain, except for three doorways on the north side.

Above the lower zone and set between the two outer members of the medial cornice, is a continuous course of dentated elements, set at an angle of 60°, the spaces between them being filled with triangular-shaped stones.

Resting on the topmost member of the medial cornice are the alternating panels of lattice and columns already mentioned. At the two front corners of the upper zone are mask panels of truly magnificent workmanship. They rank among the finest in the city. The upper zone, in turn, is surmounted by the conventional three-member cornice. The lowest member is battered, and is 9 inches high; the second is a vertical course 6 inches high, and the terminal member is a battered coping 18 inches high.

Formerly the platform and upper zone were painted red; the lower zone was undoubtedly plastered, but was not painted. The whole effect is one of dignified simplicity and striking beauty. This building is a gem of pure Maya architecture and shows no Toltec influence.

Although this temple has three doorways, at the close of the 1927 field season only two lintels had been found, namely those corresponding to the two end doorways. It seemed almost certain, however, that the middle doorway must originally have had a stone lintel as well, and that it had either been removed in ancient times and re-used elsewhere (a very common practise), or that it had been made of wood, and had decayed. Therefore, last year, in order to replace the cornice above it, it was necessary to find a substitute for this missing lintel. A plain stone lintel of the proper size was removed from an old water trough at the *hacienda*, and was used over the middle doorway in place of the missing one.

This year a more thorough bushing of the area near the temple resulted in the recovery of three pieces of the missing lintel, which were found not more than 75 feet from the front of the temple. These pieces had been refashioned into *metates*, or grinding stones, and composed about two-thirds of the original lintel. These grinding stones, the faces of which are carved with hieroglyphs, fit together, making it quite evident that they were parts of one and the same stone. Moreover, the measurements of the glyphs correspond exactly with those of the glyphs on the lintels over the other two doorways; finally the proximity of these pieces to their former position lends additional color to the conclusion that at one time they were parts of the lintel over the middle doorway. The discovery of the fragments of this lintel was gratifying, because it removes any doubt as to its former existence.

¹ This motive is identical with that found on the platform of the East Annex of the Monjas.

In addition to the discovery of the missing lintel, the more thorough bushing of the present season revealed the fact that all around the temple on the terrace itself were many small square structures, of which only the very crude foundation walls remain. Each structure measures about 10 feet square, and the foundations are composed of cut and uncut stones, both round and square. The walls of one structure abut those of the adjoining ones, forming a continuous series of small cell-like rooms. The ground-plan is not unlike the ground-plan of some of the structures in the Pueblo region of the southwestern United States.

Almost every one of these structures contains a grinding stone, or *metate*, either whole or broken. It was in two of these small cell-like rooms that the pieces of the hieroglyphic lintel were found. It is probable that the roofs of these buildings were of "jacal," i. e. palm thatch, and the sides of brush and mud.

The use of these structures is purely conjectural. They may have served as places for grinding corn; or again they may have been dwellings, although they are very small, and show no other evidence of domiciliary use, such as hearths, etc. There are from 50 to 75 of them.

At the edge of the southeast corner of the terrace is a *chultun*, or cistern, for collecting and storing rain water. This *chultun* and a nearby well were undoubtedly the sources of water for this temple and the people living in its immediate vicinity.

Report of Karl Ruppert on the Outlying Sections of Chichen Itzá

It has been felt for some time, that, in order properly to estimate the size of Chichen Itzá and to reach an appreciation of the position it held in the Maya World of the thirteenth, fourteenth and fifteenth centuries, it would be necessary to supplement the more intensive excavation work of the past four seasons with more extensive exploration of the outlying sections of the city. For this purpose a partial reconnaissance of this area was made this year. The regions explored include the territory east, south-east, south and southwest of the *hacienda*, for a distance of 3 to 4 kilometers. Where it seemed advisable to trace ground-plans, minor excavations were undertaken.

During the course of the reconnaissance some 27 stations were examined, which may be classified roughly as follows:

1. Low mounds.
2. Isolated terraces, with or without superstructures.
3. Groups of terraces and structures.
4. Stone quarries.

Examples of the first group vary greatly in extent. Walls may always be traced, often defining well-planned and extensive structures. The walls, however, are very low and the small amount of débris, together with the absence of beveled arch stones, leads to the assumption that structures of this group were of relatively small importance.

The second group includes most of the stations examined. In some cases no trace of a structure was noted on these terraces; others had a single square or rectangular mound in the center. One such mound or raised area

had, at its base, a sacrificial altar like the one found by E. H. Morris at the Temple of the Warriors in 1926.¹

In some cases, covering extensive sections of these terraces, there are irregular, square and rectangular areas outlined by a single course of stone. These may have been living quarters or work rooms, as many *metates* are found in connection with remains of this type.

Other terraces have one or more rather high mounds surmounted by a temple, or again these several types of structures may all be found on a single terrace. Sometimes isolated structures not on terraces are associated with these terrace groups.

One station, known locally as the "Group of the Chultun," is an excellent example of this kind. This name has been given to it, because of a single *chultun* here, which has a masonry drain 3 inches deep by 5 inches wide, extending from its orifice to a group of buildings on the same terrace behind it.

Besides terraces, platforms and colonnades, this group also has a type of building which is not unlike the Market Place at the Group of the Thousand Columns. This structure faces west and is composed of a colonnade, having its long axis north and south. A single opening in the east wall gives into a court some 60 feet square. A covered corridor had passed around all four sides of this court. The roof, which was flat, was supported by 20 round columns. In the middle of the east wall is a doorway leading into a small recessed chamber. During the reconnaissance, four such quadrangular structures were noted.

West of this quadrangular structure is what appears to be an unfinished ball court. The two walls are 50 feet apart and 80 feet long. The west wall is some 6 feet higher than the east wall. Because of this fact, and the absence of cut stone, it seems that this ball court may have been under construction.

Southeast of the *hacienda*, a distance of half a kilometer, a second quadrangle was discovered. This is 50 feet square, and had its entrance on the north side and an opening on the east side leading into a small chamber. The north exterior doorway is 8 feet wide. Against each jamb there is a pilaster, 29 inches wide. The faces of both of these pilasters are sculptured with hieroglyphs arranged in three vertical rows of 9 each, making a total of 54 glyphs for the two pilasters, each glyph block being 8.5 inches square.

When these pilasters were found, they were not complete. Search through the nearby bush, however, brought to light 5 of the missing pieces. The two blocks, which formed the ultimate course of each pilaster, were located 150 feet to the north, having been re-used in the construction of the southeast corner of a small platform. The opening between these hieroglyphic pilasters had been blocked at some later time, and thus the entrance to this court closed.

A kilometer east of the *hacienda*, there is a group belonging to the third type—of more than usual importance, since it contains a circular building. This building rises from a platform some 20 feet in height, which is located at the eastern edge of a large terrace. In the center of this terrace is a

¹ Year Book No. 25, p. 285.

low mound, and at its western edge is an ancient roadway leading off in a westerly direction.

The circular building itself is indicated only by the enclosing walls which stand to the height of the lower cornice, just above the battered zone. It contains but a single chamber, and is 23 feet in diameter inside. As no beveled arch stones were noted in the débris, it seems likely that the walls above the battered zone, as well as the roof, had been of wood and rubble.

Two clearly defined stone quarries (Group 4) were examined, one to the southwest of the *hacienda* and the second 3 kilometers west by north of the village of Pisté.

At the latter station, two large roughly worked blocks had been taken out and left some 20 feet from the rock ledge from which they had been quarried. Both of these blocks were broken, which may account for the fact that they had been abandoned. Each block measures 9 feet 4 inches in length, 4 feet 3 inches in height and 3 feet 10 inches in width. No artifacts were noted in or around either of these quarries.

Even the incomplete results of the partial reconnaissance made during the current season indicate a much greater building activity than had at first been suspected, and fortifies the conclusion, already reached, that Chichen Itzá was the largest center of the New Maya Empire.

Report of O. G. Ricketson jr. on the Uaxactun Project

In conformity with the contract granted by the Government of Guatemala to the Carnegie Institution of Washington for the excavation of the ruins at Uaxactun,¹ the third season was inaugurated early in January 1928. The members of the field expedition consisted of Monroe Amsden, in charge, A. Ledyard Smith and Harry E. D. Pollock, assistants.

Immediately upon arrival in camp on February 1, all hands were set to work completing and expanding the buildings erected in 1926 and 1927, clearing the year's growth, and beginning the construction of a dam across a nearby *arroyo* to provide a future water supply.

On Sunday, February 26, Messrs. Smith and Pollock left to visit a new ruin reported about five miles northeast of Juventud Station. A sketch map was made, showing extensive constructions around a main central mound 80 feet high. Two stelæ, uncarved, were found along the north border of the main plaza. The ruin was named El Paraiso.² As the party was returning from this ruin to Juventud, in as nearly straight a line as possible, it encountered a peculiar wall, 40 feet long, 12 feet high, and 10 feet thick. No other walls adjoined it; it was apparently not hollow, nor could it have served as a roof-comb.³ Its function could not be ascertained without extensive excavation, for which there was no time.

On Monday, February 27, ten workmen started clearing Group E of the annual growth, as well as an area to the west of Pyramid E-VII to make easier access to a new dump. On February 29, excavation was started on the northwest corner of Pyramid E-VII, where some of the primary construction had been exposed the previous season.

¹ See Year Book No. 25, pp. 273, 274; Year Book No. 26, pp. 256-263.

² It is located on P. W. Shufeldt and Co.'s map near a chiclé camp of this name.

³ cf. the "wall" reported in Year Book No. 26, p. 266.

The chief effort of the 1928 field season was expended in removing the outer shell of secondary rubble from Pyramid E-VII, in order to expose the primary construction beneath, which will be referred to hereinafter as Pyramid E-VII sub. In this excavation the extremely poor construction of the secondary pyramid made it impossible to obtain very detailed information, though it was ascertained that stairways had ascended to within 20 feet of the top on all four sides. The apex of the pyramid was the latest addition; inasmuch as six horizontal strata of compact dirt and very small stones were found in this apex, it may well be that each stratum represents an original capping to the whole. These strata were each 6 inches deep and occurred at the following levels, numbering from the top down and measuring the height from the plaza floor: 1, 45 feet; 2, 42 feet; 3, 41 feet; 4, 39 feet; 5, 36 feet; 6, 32.5 feet. The greatest height of the pyramid, ascertained the previous years, was 50 feet.

In the coarse rubble forming the hearting of the apex three cysts were found: Cyst 10, lying on the fourth floor, at the 39-foot level; Cyst 11, on the fifth floor, at the 36-foot level; and Cyst 12 lying between the fourth and fifth floors, about 1 foot higher than Cyst 11.

Cyst 10 was a rectangular grave of large, cut, untrimmed stones and mud. Its long axis extended east and west. It contained the headless skeleton of a female, whose age was estimated as 25 years. The skeleton lay fully extended, face down, the feet toward the west, the right arm extended beneath the pelvis, the left arm flexed with the hand under the left shoulder. The grave itself was 20 inches wide and 5 feet 6 inches long. The west end of the grave was 5 feet 6 inches from the nearest point on the outside face of the pyramid, the east end 4 feet, and the south side 8 feet. At this level the summit of the pyramid measured approximately 25 feet north and south and 15 feet east and west. The grave was closed with a layer of very small stones. There was a space of 6 inches between the first vertebra and the east wall of the grave.

Cyst 11 lay just north of Cyst 10, though at a lower level. It was semi-circular in shape, with the flattened base of the semi-circle to the west and in line with the west end of Cyst 10, and the apex of the curve pointing to the east. It measured 3 feet along the base, north to south, and 2.4 feet along the mid-line, east to west. It contained six pots, three plain redware dishes with flaring rims and three plain brownware cylindrical pots with covers. These were similar to the dishes and pots found in Cysts 1 to 9 in Temples E-I, E-II, and E-III the previous season. Large stones were placed in this cyst to prevent the weight of the superimposed earth from crushing the vessels. The floor of the cyst was formed of a compact stratum of mud and small stones.

The redware dishes (Nos. 1, 2, 3) were stacked in the extreme northwest corner, the two lower dishes one inside the other and the third dish inverted so that it lay rim to rim with the inner bottom one. All were 6.5 inches in diameter at the top, 4.5 inches at the bottom, and 1.75 inches deep.

The brownware cylindrical pots (Nos. 4, 5, 6) were placed in a line running diagonally across the cyst, *i. e.* toward the southeast, from the redware dishes. No. 4, lying nearest Nos. 1, 2 and 3, measured 5.5 inches

in diameter and 5.5 inches in height; No. 5, next to No. 4, was 5.25 inches in diameter and 5.5 inches in height; and No. 6, next to No. 5, was 5.5 inches in diameter and 5.25 inches in height.

Of the redware dishes, the upper (No. 3) and the lower (No. 1) were cracked; No. 2 was intact. Of the brownware pots, No. 4 had the cover broken in excavation; it contained two (jade ?) beads, one with red paint on it, and flakes of some silvery colored material; No. 5 was intact and also contained silvery colored material and some partially dried brown gummy material; No. 6, also intact, contained both the silvery and the brown material (some of the latter still adhering to the sides) and seeds resembling those of the squash.

Cyst 12, like Cyst 11, was semi-circular and occupied the same relative position on the south side of Cyst 10 that Cyst 11 did on the north. (For level, see above.) It measured 3 feet both along the base line, from north to south, and along the mid-line, from east to west. It contained seven pieces of pottery in all, two plain redware dishes with flaring rims, the top one (No. 1) inverted over the bottom one (No. 2), and five plain brownish-redware cylindrical pots with covers (Nos. 3, 4, 5, 6, 7). The dishes were placed along the northeast arc of the cyst (at "eleven o'clock," in the parlance of target shooting), and the cylindrical pots were placed irregularly in the central east and west zone from base to apex. As in Cyst 11, stones placed in the open space prevented the earth above from crushing the pottery.

The two redware dishes were 5 to 5.25 inches at the base and 9.5 inches in diameter at the rim, and 2.25 and 3 inches in height. Both were cracked, and in the space between them were two snake's eggs, small pieces of charcoal and a sandy substance with a reddish tinge. The pots measured from 5 to 6 inches in diameter and 4.75 to 5 inches in height. They were intact and contained variously shells, seeds, a silvery substance, partially dried gummy material and a reddish material on the bottom. No. 7 also contained two pieces of obsidian, and between Nos. 3 and 4 was found an obsidian lancet, measuring 6.5 inches by 0.5 inch, extremely sharp and well made.

Two other redware dishes with flaring rims were found in secondary rubble at the level of the seventh terrace, just along the north balustrade of the secondary stairway. This cache is called Cyst 9, though the dishes were imbedded in solid mud. The top dish was inverted over the bottom one, but nothing was contained between them except three stones—each measured 10 inches in diameter at the rim, 6.5 inches in diameter at the base, and 2 inches deep.

In the new clearing made for the laborers' camp, an *olla* and pitcher of coarse brownware, of more recent manufacture, were found lying on the ground. The *olla* measured 8 inches from the rim to the tip of its conical bottom; its greatest diameter, 11.5 inches, occurred just below the very slight constriction under the everted lip. The pitcher was 7.5 inches in depth and the same in diameter.

After the removal of the secondary rubble from Pyramid E-VII (except from the southwest corner, purposely left covered as a control), Pyramid

E-VII sub was exposed practically in its entirety. It consists of a terraced platform, with seven different levels. It measures 25 feet in height, 79 feet north and south, and 76 feet east and west at the plaza level. Four main stairways, each composed of three flights of six steps each, mount the centers of the four sides from the base of the pyramid to the level of the fifth terrace. From this level one more flight of five concavely curved steps mounts, on the east side only, to the level of the sixth terrace, the posterior two-thirds of which is raised about one foot to form a low platform called the seventh terrace. The stairway on the east side, which faces the plaza and is the main façade of the structure, is bounded by six large stucco masks, three on either side, and the stairways on the other three sides are bounded by four similar masks each, two on either side. There are, therefore, eighteen masks on the whole pyramid; these have been numbered 1 to 18 according to the following plan: Nos. 1 to 8 are the masks of the lowest tier, beginning with the mask south of the East Stairway and passing around the pyramid counterclockwise to No. 8 on the east side of the South Stairway; Nos. 9 to 16 are the masks of the tier above, beginning again with the mask on the south side of the East Stairway just above No. 1 and passing around the pyramid counterclockwise to No. 16 just above No. 8; Nos. 17 and 18 are the masks of the third tier and lie on the south and north sides, respectively, of the five concavely curved steps which lead from the fifth terrace to the sixth and seventh terraces on the east side only.

Masks No. 2 and No. 10 were uncovered in 1927 and the description of No. 10 already given¹ will roughly suffice for all the masks in the second tier. Although no two masks are identical, all are strikingly similar in the following respects:

- (1) Each mask is, roughly, 8 feet square.
- (2) All are made of lime stucco, over a built-up stone core.
- (3) All are of good workmanship, in rather low relief, and primitive rather than sophisticated in treatment.
- (4) The mouths of all appear as narrow, sunken slits from which depend two lateral, outward-curling fangs, and one central, more ornate, roughly heart-shaped appendage which might be tooth or tongue.
- (5) All the noses have a specialized decoration, either a tapered roll ornament hanging in a catenary curve between the eyes, or three parallel horizontal bands with gently rounded edges.
- (6) All have conventionalized head-dresses, perhaps representing feathers, the elements of which are flowing scrolls, untapered and ending in curls with the characteristic Maya blunt tip.
- (7) The expression of each mask is grotesque, ferocious.
- (8) The ears, depicted as without ear-plugs, extend the full height of the mask, and are in every case extremely conventionalized.

The lowest tier of masks, Nos. 1 to 8, are even more difficult to describe, for they are in such bad condition that their original character is scarcely recognizable. They suggest nothing so much as highly conventionalized serpents' heads, but this fact runs counter to the hypothesis that the cult of

¹ See Year Book No. 26, pp. 257, 258.

Kukulcan or the Feathered Serpent was a late Aztec or Toltec influence among the Maya. It is hoped that better preserved and less debatable examples may turn up in further excavation. These masks are approximately 8 feet wide and 6.75 feet high. About 16 inches of the top extends above the level of the fourth terrace. The upper half of each mask is composed of conventionalized scrolls, one of which curls in such a way on either side as to suggest eyes. Across the center of the mask is a horizontal slit obviously representing a mouth, and in it are pointed teeth, but the lateral pendant curling fangs associated with the Feathered Serpent in northern Yucatan are absent. Below the mouth, in the center, hangs an oblong appendage upon which is shown in slight relief a tongue with two outcurling scrolls; this design, suggesting the bifurcated tongue of a snake, is often seen in northern Yucatan in connection with representations of the Feathered Serpent. The lowest third of the mask, countersunk deeper than those portions described above, appears to represent the throat. It shows a dentate design in two horizontal rows, the points down, much like triangular-tipped shingles on a house, and this has been interpreted as a crude representation of feathers or scales; this part of the design certainly does not represent teeth.

The two masks bounding the East Stairway at the level of the fifth terrace, Nos. 17 and 18, are smaller and more ornate. They measure 5.6 feet and 6.6 feet in width, respectively, and 5 feet in height. Each represents a human face with a large, out-curling fang hanging from either side of the mouth. The face is framed by a scroll head-dress above and ears with large ear-plugs on either side. The nose, decorated with a tapered roll hanging in a catenary curve, is greatly exaggerated in both masks, and extends down in front of and beyond the mouth. The foreheads of both are decorated with a plain plaque in the center. Both these masks show traces of red paint. In this connection it may be noted that Mask No. 10 had a red line, 3 inches long and 0.125 inch wide, on the left cheek, but the rest of the face had apparently never been painted.

Besides the main stairways facing the four cardinal points on Pyramid E-VII sub, which is accurately located in respect to the true or astronomic points of the compass, there are decorative steps on the various terrace levels below the fifth. They occur just outside the masks (except in the case of Nos. 17 and 18, which are above the fifth terrace), and are approximately 4 feet wide. Compared to the main stairways, which are 9 to 10 feet wide, they seem very small and could have served no essential function other than to give access to all parts of the masks' faces. The first three flights lead from terrace to terrace, these three terraces being but 3 feet high each; the fourth and topmost flight ascends only 4 feet of the 9-foot high fourth terrace, ending against sheer wall too high to climb. The first three terraces and the fifth have simple cornices; the fourth terrace has both a plain basal cornice, 18 inches high, and a band, 2 feet wide, raised in relief 2 feet down from the top of the terrace.

The measurements of Pyramid E-VII sub at plaza level have already been given. The four main stairways which run to the top of the fifth terrace give access to an area 33 feet north and south, 20 feet east and

west, on which is located (3 feet back from the top of the East Stairway) a low mound or platform of two levels which form the sixth and seventh terraces. This platform is 4.5 feet high in front and 5.5 feet high in back, the step-up occurring 3.5 feet from the top of the concavely curved flight of five steps, bounded by masks Nos. 17 and 18, which already have been described. Four cysts were found in this platform, Cysts *d* and *e* on the lower level near the front, and Cysts *f* and *g* on the upper level near the back. No objects were found in these cysts and Cyst *f* is typical of all four. This cyst was a circular hole, 14 inches in diameter and 52 inches in depth. Its outlines were sharply definable. A hole 25 inches in diameter had been dug through the 11-inch thick black flooring, and Cyst *f* had been sunk at the southern side of this; 5 inches to the north lay a very small cyst, *f'*, only 6 inches in diameter and 2 feet deep. Cyst *f* contained about a foot of brown mold and some charcoal in the bottom, which suggests the possibility that these four cysts, each with a little cyst accompanying it, served as post-holes for the timbers of a wooden structure on the top of the pyramid. These cysts had been sealed with white plaster at floor level, presumably after the posts had been removed and the secondary pyramid constructed.

Toward the close of the field season, Dr. Kidder and Dr. Morley, and Dr. G. C. Vaillant of the American Museum of Natural History, New York, visited the ruins, Dr. Vaillant coming as ceramic expert upon the invitation of the Carnegie Institution of Washington.

Although the excavation of Pyramid E-VII sub had occupied most of the field season and brought to light for the first time a new type of early Old Empire temple hitherto unknown, unique in style and with interesting variants of the usual Maya features, a most important discovery during the season is due to the work of Dr. Vaillant who sank exploratory trenches at two positions in the plaza and ably interpreted the information gained thereby.

The first of these trenches (Trench No. 1) was sunk at right angles to the east face of Pyramid E-VII sub, a few feet south of its northeast corner. Trench No. 2 was then dug at right angles to No. 1, due south to Stela 20. A third trench, Trench No. 3, was dug on the east side of the plaza, in front of the space between Temples E-I and E-II and north of Stela 18. Conditions here were almost identical with those found in Trenches Nos. 1 and 2; floors presumably corresponding to those already found in Nos. 1 and 2 were observed to run beneath the substructure of Temples E-I, E-II, and E-III, indicating the probable presence below the substructure of an earlier building, perhaps synchronous with Pyramid E-VII sub.

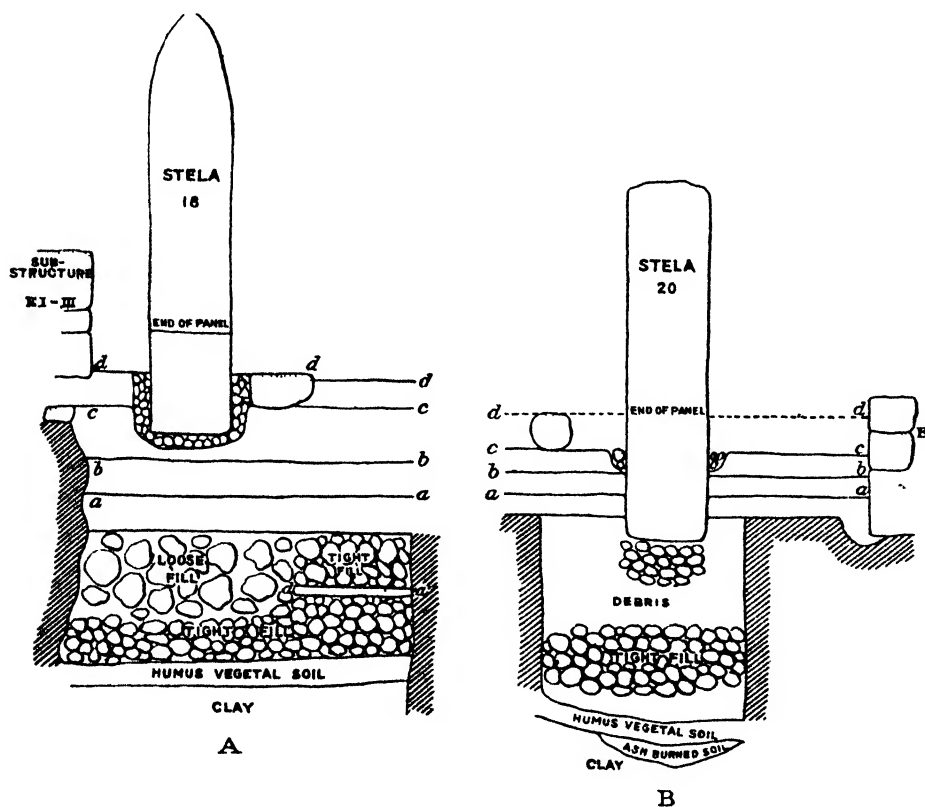
Dr. Vaillant's report is given in full on page 314.

The 1928 expedition is again indebted to the following persons for their many courtesies: to Mr. and Mrs. P. W. Shufeldt and Mr. C. O. Taylor of Belize; to Mr. Robert Masson, of His Majesty's Customs, Belize, and to Mr. G. P. Chittenden of the United Fruit Company. Mr. Ricketson, on temporary leave of absence from the field, is personally indebted to the members of the field staff and to Dr. Vaillant for their efforts in obtaining the material for this report, and for their cooperation in its preparation.

Report of G. C. Vaillant on the Excavations in the Plaza of Group E at Uaxactun

A feature of the season's excavations at Uaxactun was the discovery of conditions favorable for an examination of the relationships between the stelæ and the structures at Group E. The close of the season prevented a definite interpretation of the data gained, but the historical implications are of considerable import.

The presence of Stela 20 and the primary and secondary pyramids of E-VII gave every promise of fruitful correlation and research. The first step was to find bottom, and from this preliminary pit (Trench 1) trenches were run west to the primary pyramid and south to Stela 20 (Trench 2). It was possible, therefore, to observe from two sides the stratification. Later, eastward by 150 feet across the plaza at Stela 19, a trench (Trench 3) was dropped to study the relationships at that point. Unfortunately time was lacking to join by trenching the operations at Stela 20 and Stela 19.



Excavations in the Plaza of Group E at Uaxactun

A. Trench 3 on east side of plaza near Stela 18.

B. Trenches 1 and 2 on west side of plaza near Stela 20.

The conditions in Trench 1 comprised a series of four floors overlying a layer of perhaps redeposited refuse. This deposit rested on a fill of rocks mingled with charcoal, potsherds and vegetal débris. Underneath this layer stretched a thin stratum of what appeared to be humus, and excavation was stopped after producing pure clay for a foot. In the southwest

corner of this trench a pit was dug through the humus into the clay containing ash, burned kernels and burned rocks. This deposit represented, doubtless, a firepit. In Trench 2, excavations were carried only a short distance into the rock fill. Between the fill and the base of the floor occurred the very fragmentary remains of a young adult burial, with two jade beads near the neck.

Beginning from the bottom of the series of strata in Trench 2, we observe, from the section in the accompanying figure, that the original occupation surface was thinly covered with humus on the clay subsoil. Above this is a thick layer of stones mixed with sherds and charcoal. This section looks more like a leveling process in which rubbish layers were spread out and redeposited, than the natural accretion of human refuse. Yet, curiously, above this stone layer the earth is soft again but without the laminations and lenses of ash, vegetal and other débris that are characteristic of most deep rubbish beds.

Resting directly on this soft bed is the primary pyramid, E-VII sub, and extending from its base is the hard white plaster Floor a-a. Directly above, and at times indistinguishable from Floor a-a, is Floor b-b. This latter surface seems to be in the nature of an element of repair and not part of any extensive system of architectural change or addition.

Floor c-c seems to be the product of a plan of alteration. The original pyramid, as described in the preceding report of O. G. Ricketson jr., rises in corniced steps. Unfortunately our section is taken through a different part of the building, *i. e.* through the balustrade, and does not show this condition. Floor c-c, however, is carried out from the base of the cornice, so that this latter architectural feature disappears. This willingness to sacrifice to the new floor level a significant architectural feature must signify some important external change, perhaps the construction of additional buildings in another part of the plaza.

Floor d-d, the topmost surface, is so badly destroyed by the action of roots and trees that only a vestige remains around the base of Stela 20. However, since the first three floors we have considered belong to the primary pyramid, this fourth must be associated with the covering or secondary pyramid. Stela 20, of early date, 9.3.0.0.0, must be associated with this latest floor, since a cup-shaped hole was excavated through the lower floors to receive the shank of the stela. The lower edge of the frame of the sculptured panel was a little above Floor d-d.

Across the plaza, 150 feet to the east, Stela 18 is situated immediately in front of the long substructure on which rest Temples E-I, E-II, and E-III. A trench (Trench 3) was dropped to the north of the monument to find out the relationships of substructures, floors and this stela, which bears the very early date of 8.16.0.0.0. The conditions in the main are very similar to those in Trenches 1 and 2 on the opposite side of this plaza.

In Trench 3, the bottom layer is of clay with a thin layer of humus containing a very few sherds. The next stratum is composed of stones mixed with débris, and from this layer came most of the sherds. At the west end of the trench, a thin plaster floor, a'-a', resting on this level, was exposed. There was not, however, any trace of walls. Perhaps they had been of wattle-work.

Directly above a'-a' is a fill of the same character as below it—dirt and stone mixed. East of a'-a' the upper fill is of pure rock with no dirt in the interstices. In the accompanying figure this condition has been labeled "loose fill"; the state of the lower strata, where the interstices are filled with soil, is entitled "tight fill."

Above this last-mentioned stratum is a thick solid floor a-a, which, as in Trenches 1 and 2, is of plaster, lime and the residue from burning lime. Directly over this floor is another equally hard, b-b. Both these floors pass under the eastern substructure of the plaza of Group E. Up to this point the conditions are practically homologous with those in Trenches 1 and 2.

Floor c-c is thicker than the equivalent surface in the western trenches, comprising a foot and a half of material. Directly under the west face of the substructure of Temples E-I to III, there is a stone which may represent a coping. If this be so, there is a strong presumption that the development of the E group was out and east from the primary pyramid of E-VII.

Floor d-d is clearly represented in Trench 3 by a surface coped with stone around Stela 18. This floor is definitely associated with the substructure of Temples E-I to III, since the lower floors all pass beneath it. Stela 18 is set in a cup-shaped depression, and is wedged firm by small stones. The socket extends through Floor c-c to a little above Floor b-b. It is not so deeply set as Stela 20. Another point is that while Stela 20 is set with its long axis parallel to the secondary pyramid of E-VII, Stela 18 is slightly askew to the substructure with which it now corresponds.

Levels were not taken to compare the floors, but in the stratigraphical complexes of Trenches 1-2 and Trench 3, the number of surfaces is the same. The greater thickness of the floors in Trench 3, taking the surface a-a as a fixed level for measurement, is merely an increase of between 6 inches and a foot in a distance of a little over 150 feet. While a linking of Trenches 1 and 2 with Trench 3 would give more complete data, the correspondence is close enough to permit the drawing of certain conclusions from the data at hand.

Of the original contour of the low hill upon which Group E is situated, we have as yet no information. Yet the first occupants must have lived directly on its surface without making any great effort to adjust its probable irregularities by leveling or terracing.

As time went on, however—and judging from the depth of the débris, it was a considerable period—there must have been some rude attempt at leveling, as the presence of so many stones in the débris attest. But in this stone layer there are also many sherds. This combination seems to indicate a shoveling of débris from the top of the hill to level off the surface. Substance is added to this hypothesis by the presence of Floor a'-a' in Trench 3.

However, after this leveling, occupation must have continued for some time, since in Trenches 1-2 we find pure débris and a skeleton above the stone fill. It would facilitate interpretation of ground conditions if we knew whether it was a Maya custom to bury in rubbish beds which were contemporaneously accumulating. It is not so easy to account for the fill above Floor a'-a', which contains stones.

Pottery found in the levels below the a-a floor system consists of wares with yellow-white, red, brown to black, and grey slips. The first three wares have a flaky base clay, but the slip is hard. The grey ware is porous and powdery, and is used for storage vessels. The yellow-white ware is rarely painted in red, but sometimes a red secondary slip is coated over it. The brown-black ware is decorated mainly by incision and by modeling. The shapes for the red and the yellow-white wares are low squat dishes with concave bottoms, or deeper vessels, almost conical. The shapes in brown-black wares are globular bowls, *ollas* of small size, and cylindrical vessels. Associated with these pot forms are figurines with modeled bodies; in technique the faces are on the border line between molding and modeling. In expression some heads begin to show Maya features, although there is a "feeling" of the plastic of the unspecialized cultures of Middle America (the so-called Archaic). An owl-whistle was also found. Summing this material up, it seems to be in pot-form, non-Maya, but, in the plastic art, just emerging into that type called Maya. While not resembling it in any but the most general way, the nearest ceramic group is the material found by Dr. Gamio at the Finca Arevalo just outside Guatemala City.

Directly over this lower level material, stretches the Floor a-a which is associated with Pyramid E-VII sub. From the preceding report, it will be seen that this structure is not in the Peten tradition of steeply rising slopes broken by narrow terraces. While the masks give the structure a Maya flavor, the stepped profile recalls the pyramid types of the Highlands of Guatemala, although it seems improbable that there is contemporaneity between the latter and this undoubtedly early building. Possibly E-VII sub belongs to a common ancestral type.

It will be of the greatest interest to find other structures in Group E of the same period as E-VII sub. The conditions in Trench 3 seem to make such a find likely, for, not only did the floors pass under the substructure of Temples E-I to III, but there is also a formal foundation of dry stone (loose fill), that suggests a considerable enlargement of the original hill top. Floor b-b was laid apparently as a repair surface, but Floor c-c seems to be a connective floor, for the rise in level is more than necessary for the needs of repair. The bringing of Floor c-c up to the cornice level of E-VII sub tends to confirm this assumption. Not enough material was found to indicate the ceramic styles of Pyramid E-VII sub, or the Floor c-c period, for the rubbish deposits of these horizons were not encountered.

As explained above, Floor d-d is the surface associated with E-VII, the substructure of E-I to III, and Stelæ 18 and 20. But there is a difference of 138 years in time between these two stelæ. At the present we can not say which of the stelæ is contemporary with Floor d-d, nor can we show that neither is contemporary with the architecture, having been removed from some other locality and reerected here. It is significant that Stelæ 18 and 19 are badly aligned with the substructure behind them, hinting perhaps at the presence of an earlier structure, but the juncture of Floor d-d with this substructure militates against this assumption. In the masonry forming Pyramid E-VII sub, a fragment of a bowl was found that resembles

so closely as to be stylistically identical with a vessel found in the second of four groups of burials at the stratified, apparently Old Empire, pyramid of Holmul.

The other pottery in the fill also carries the characteristic style of Holmul pottery comprising vessels with porous base clays, and black or red slips like a lacquer. Storage pottery is of porous friable grey-ware striated on the exterior. In shape, the red-and-black-ware bowls are composite silhouette rim bowls with broad flanges at the point of union between the rim and the base sections.

The pottery from Temples E-I, II and III, from a casual inspection, seems different from this style, showing cylindrical legs and an absence of the flange, having some resemblance to the latest ceramic period at Holmul. The small stone idol discovered in the season of 1927 might be assigned to the sub-floor period of Pyramid E-VII, but this classification is conjectural.

In short, then, at the E Group at Uaxactun, there was a long period of occupation, punctuated not only by architectural changes in structure, ground-plan and level, but also by changes in the major and minor arts. A complete series of trenches would yield that which the archæology of the Maya most needs—a chronology based on material culture—and possibly even a correlation between the stelæ which record absolute time and the sequence of the material culture. We have then the following phases:

1. Original occupation.
2. Floor a'-a' and expansion of the town of the first inhabitants.
- 2a. Possible abandonment of this town, as seen by the burial in Trench 2.
3. Construction of Pyramid E-VII sub and Floors a-a and b-b.
4. Expansion of site of E-VII sub people as seen by Floor c-c.
5. Construction of Pyramid E-VII sub, and the substructure of Temples E-I to III. Insertion of stelæ. (Stelæ 18 and 19 may represent a period intermediate between 4 and 5, and people of that epoch may have made the pottery in the fill of Pyramid E-VII.)
6. Occupation of the people who left their pottery in Temples E-I, E-II and E-III, and who, perhaps, may have built these temples.

The great point raised by this season's excavation is, how high a culture, as Pyramid E-VII sub attests, existed before the erection of stone monuments by the Peten Maya. We may have discovered the origin of "Maya" culture, but we have yet to find the mother-culture of its originators.

Report of S. G. Morley on the Ekbalam Expedition

On June 4, Dr. Morley and Mr. Charlot left Chichen Itzá for Valladolid, and thence north 15 miles to the ruins of Ekbalam. This site had been previously visited and described by the French explorer, Charnay,¹ but a recent report of a hieroglyphic inscription there indicated the advisability of further exploration.

Ekbalam must have been a center of some importance judging from the size and extent of the remains, although comparatively late. The buildings

¹ *Ma dernière expedition au Yucatan 1886*. Texte et Dessins inédits. In *Le Tour du Monde*, pp. 298-304, by Desiré Charnay.

are low and built of crudely dressed masonry. Carved or even cut stones are almost entirely wanting, and the walls seem to have been finished, for the most part, with stucco as at Tulum. The very low height of the corbelled arch, in the single intact chamber seen, strongly recalls the similar low arched chambers of the buildings along the East Coast, which are certainly of late origin, having been occupied down to the time of the Spanish Conquest. On architectural and stylistic grounds, it is more than probable that Ekbalam was a contemporary of Tulum and the other East Coast sites, and that it too was occupied until the early part of the sixteenth century.

One of the highest pyramids had a human figure made of stone and stucco on one side of a doorway leading to a chamber near the top. This was very grotesque, crudely executed and without esthetic merit.

A large altar 7 feet long 3 feet wide and 3 feet high, carved from a single block of stone, was found standing by the out-cropping of the native limestone from which it had been quarried. Its entire top had been hollowed out to the depth of 5 or 6 inches, leaving a rim 4 inches in thickness. The front is carved with a grotesque human face having large circles around the eyes, suggesting the Tlaloc head; the back and sides are plain, though dressed.

A single carved stela was found in a similar position, *i. e.* lying on the ground by a similar out-cropping of the limestone. This had a rounded top and a small simplified serpent with a plumed head-dress on the front. There were no glyphs on this monument and the back and sides are plain, though dressed.

Ekbalam was obviously a late provincial center, and its architecture and sculpture are such as might be expected in a Maya site of this last degenerate period in the northeastern corner of Yucatan.

Report of S. G. Morley on the Pusilhá Expedition

The ruins of Pusilhá are located in the extreme southern part of British Honduras, about a mile east of the Guatemala frontier, on a point of land between the Pusilhá and Machaka Rivers, which unite here to form the Mojo River. Hills surround the site on all sides, enclosing a valley of very great fertility; even today the rain-fall is so excessive, probably being between 140 and 150 inches, that it is possible to raise three crops of corn a year.

There are the remains of an ancient bridge over the Pusilhá River—two stone piers, perhaps 20 feet high 30 feet long and some 30 feet apart, one on either side of the river. The sides of these piers, facing upstream, have been given concave outlines so that logs coming down at high water and striking them would be diverted toward the middle, and thus more easily pass beneath the bridge without blocking.¹

The word *pusilhá* means in Maya, *pusil*, stagnant; *há*, water, *i. e.* stagnant water, a name possibly derived from some fancied characteristic of the river of the same name which flows by the group.

¹“Report on the British Museum Expedition to British Honduras, 1927” in the *Journal of the Royal Anthropological Institute*, vol. LVII, p. 315.

Pusilhá was discovered during the summer of 1927 by Mr. James R. Mason, in charge of the mahogany operations of Mr. Lee Pierce of Punta Gorda. Mr. J. Eric S. Thompson of the Field Museum of Natural History, Chicago, visited the site a few months later and deciphered four of the Initial Series there, those on Stelæ D (first Initial Series), K, M and O.¹ See table below.

In December 1927 and again in March 1928, Dr. T. Gann visited Pusilhá on behalf of the British Museum, spending 5 weeks at the site during his second visit and removing four of the monuments, Stelæ M, O, P and Q, to Punta Gorda for transportation to the British Museum. On his second visit Dr. Gann deciphered three additional dates, Stela H (first Initial Series), Stela Q and Stela Y (first Initial Series). See table below.

Dr. Morley was at Pusilhá from May 5 to May 7 and deciphered five other dates as follows: Stela D (second Initial Series), Stelæ E and F, and Stelæ H and Y (second Initial Series). A complete list of the dated monuments at Pusilhá, arranged in their chronological sequence, is given in the following table:

Monument	Maya date	Christian Era	Kind of Date
		A D.	
Stela O.....	9. 7. 0.0.0	314	Initial Series
Stela Q.....	9. 8. 0.0.0	334	Initial Series
Stela F.....	9. 9.13.0.0	367	Period Ending
Stela D.....	9. 3 ^a .0.0.0	334	Initial Series
Stela D.....	9.10.15.0.0	388	Initial Series
Stela Y.....	9. 7. 0.0.0	314	Initial Series
Stela Y.....	9.10.15.0.0	388	Initial Series
Stela H.....	9.11. 0.0.0	393	Initial Series
Stela H.....	9. 7.12.6.7	326	Initial Series
Stela K.....	9.12. 0.0.0	413	Initial Series
Stela M.....	9.14. 0.0.0	452	Initial Series
Stela E.....	9.15. 0.0.0	472	Initial Series

There are 20 monuments in the principal plaza at Pusilhá, all but two of them (Stelæ U and Y) on the south side in front of Mound I. Of these, the dates of nine have been deciphered (see above). Three others, Stelæ N, P and U, formerly had Initial Series, a fact proved by the presence of the accompanying Supplementary Series in each case, but they are now too effaced to permit decipherment. The Supplementary Series of Stelæ P indicates that its Initial Series may have been 9.13.0.0.0. The remaining eight monuments, Stelæ A, B, C, G, L, R, S and T have their inscriptions entirely destroyed. Indeed in the cases of most of these monuments, the only parts which have escaped the ravages of time and weather are the butts, the upper parts having completely eroded away. There are 14 Initial Series and 1 Period Ending date.

¹ See Field Museum of Natural History. Annual Report of the Director to the Trustees for the year 1927, p. 215. Also, *Some New Dates from Pusilhá in Man*, vol. xxvii, No. 6, p. 95, by J. Eric S. Thompson.

² The katun coefficient in this Initial Series is recorded as 3. Katun 8, however, is clearly recorded in Glyph A8, and Glyph A7b may represent its corresponding month position—3 Chen. In any event the contemporaneous date of Stela D is not the first but the second Initial Series, 9.10.15.0.0.

There is not a single standing stela in the city, most of them having fallen backward instead of forward, thus preserving the inscriptions on their backs, rather than the human or divine figures, which had been carved on their fronts. Only one monument, Stela C, has a well-preserved figure; this shows a gorgeously dressed individual clasping a double-headed ceremonial bar diagonally across his breast.

The dates at Pusilhá indicate a fairly early Old Empire site, founded some time toward the close of the Early Period. Stela O, stylistically as well as chronologically, is the oldest monument, the early technique of its glyphs, showing irregular outlines agreeing with the early date recorded upon it. Six of the nine dated monuments (Stelæ O, Q, H, K, M and E) were erected on katun-endings; two (Stelæ D and Y) on hotun-endings, and one (Stela F) on an oxlahuntun-ending. It is to be supposed that some of the other monuments, the inscriptions of which are effaced, filled the existing lacunæ in the chronological sequence.

Stelæ D, H and Y have a characteristic shared by but two other monuments in the whole Maya area; Stelæ 1 and 6 at Macanxoc-Cobá,¹ that is each has two Initial Series instead of one, the second Initial Series in each case, following in the body of the text some distance after the first Initial Series. As the Initial Series were originally so named by A. P. Maudslay, the English explorer, because of the fact that they always stand at the beginning of inscriptions where they appear,² the 5 cases given above are the only examples of their kind now known in the *Corpus Inscriptionum Mayarum*.

Stela K at Pusilhá shares with Stela 4 and Altar I at Copan and Stela 10 at Tikal an even greater distinction, these four monuments being the only ones known where the Initial Series stands elsewhere than at the beginning of an inscription. The Initial Series on Stela K at Pusilhá stands at the top of the third and fourth columns of glyphs from the left, instead of the first and second, or the first alone, the position elsewhere.³

The latest date at Pusilhá, 9.15.0.0.0, on Stela E, indicates that the city was occupied, at least down to the beginning of the Great Period. But how much longer it continued to be occupied—before it was abandoned—is a matter of conjecture, failing the positive evidence of dated monuments. It is not improbable, however, that Pusilhá ceased flourishing as a center of population sufficiently important to erect monuments commemorating the katun-endings, well before the beginning of Baktun 10,⁴ and by 10.3.0.0.0 when the last monuments seem to have been erected in the Old Empire region,⁵ it probably had been completely abandoned.

¹ See Year Book No. 25, p. 275.

² *Biologia Centrali Americana*, Section on Archaeology by A. P. Maudslay, vol. I of text, p. 40.

³ See Carnegie Inst. Wash. Pub. No. 219, pp. 190-193, and 356.

⁴ The latest date near Pusilhá is 9.18.5.0.0. on Altar 1 at Cancuen, some 30 miles westward in Guatemala, discovered by the First Central American Expedition in 1915. See Year Book No. 14, pp. 344, 345.

⁵ Stela 10 at Xultun (Year Book No. 19, p. 322) and Stela 12 at Uaxactun (Year Book No. 21, p. 315) are the two latest Old Empire monuments known; both of them record this date.

BIOLOGY

Castle, W. E., Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3-26.)

In the two major problems in rabbit inheritance mentioned in my last report, substantial progress has since been made. Several hundred young have been reared of the critical backcross generation required to show whether larger size is inherited in association with a group of genes introduced from a large race in a cross with a small race. Not all the animals reared in this experiment are yet old enough to allow of their classification as to adult size, but a preliminary study of the data gives no indication of association. This conclusion, if confirmed by study of the complete data, will raise a question as to whether ordinary genes are involved in the inheritance of size and other quantitative characters blending in heredity. Doubt has long existed concerning this matter, but for some years the multiple factor hypothesis has been accepted as a fairly satisfactory though unproved solution of it. This hypothesis was originally based on the existence of plural genes for qualitative characters, such as color of the seed coat in wheat and oats. Such facts are fully accounted for on the assumption that the same color gene is found in two or more different chromosomes. This, in turn, is explicable on the ground of the polyploid character of the cereals involved. The assumption that plural genes affecting quantitative characters may also be the explanation of size inheritance remains to be proved. A certain amount of linkage has been shown to exist between flower color and time of flowering in peas, and between color and size or shape of the fruit in tomatoes, but it remains questionable whether these are not special cases and to what extent one may generalize from them. Fruit size is very different from general plant size or general body size in animals.

Several years ago, with the assistance of Dr. Sewall Wright, I worked out a mathematical formula for applying the plural gene hypothesis to cases involving the inheritance of quantitative differences. Several investigators (including myself) have attempted to use this formula, but without very satisfactory results. One author rejected it because it did not cover cases involving differences in magnitude of effect or in dominance between members of the assumed plural series. Others obtained results which seemed improbable or absurd. It does not seem to have occurred to anyone that the basic hypothesis of the multiple factor hypothesis might be wrong rather than the formula by which it was applied.

Our experiments with rabbits show conclusively that size is inherited as effectively through the sperm as through the egg of the rabbit. This renders highly probable the assumption that a chromosome mechanism is involved. But it throws no light on the question whether definite loci in the chromosomes influence the inheritance of general body size, as they do the inheritance of hair color, hair structure, or other mendelizing characters.

It is possible that a quite different mechanism is involved. We hope in time to get further light on this question.

Supplementing the direct study of size inheritance in rabbits, two graduate students have been working on other aspects of the same problem. Dr. R. C. Robb has studied the endocrine glands, and in particular the pituitary, as a possible mechanism by which genetically determined size differences become effective, but concludes, on evidence which is very convincing, that they are not such a mechanism (see *Proc. Nat. Acad. Sci.*, 14, 394). Dr. P. W. Gregory has been engaged in a study of the early embryology of the rabbit with a view to ascertaining how early in development size differences are recognizable. In this study we have had the invaluable cooperation of the Department of Embryology, for which hearty thanks are due to Dr. G. W. Streeter. Dr. Painter had already found (see *Year Book No. 26*) that there is no difference in size of egg-cell in large as compared with small races of rabbits, but that a difference was already established in 9-day embryos. Our study of the intervening stages is still in progress, but we find a significant difference already established at 6 to 7 days—before the primitive streak is fully established and long before any definitive organs of the body are laid down. The difference is recognizable not only in the size of the entire blastodermic vesicle, which is still unattached to the uterine wall, but also in the size of the embryonic area visible as a thickening in the wall of the blastodermic vesicle. This result shows that growth is for some reason more rapid in an embryo of a large sized race, though differentiation is not more rapid. There is indeed reason to think that differentiation is really less rapid in the larger race, since the small race has a gestation period about one day shorter (31 as against 32 days) and attains sexual maturity earlier by 2 or 3 months. Greater adult size in the larger race is thus attained through accelerated growth and retarded puberty. The acceleration in growth is already in evidence long before any endocrine or other organs of the body have been differentiated, which supports the conclusion of Robb that internal secretions are not concerned in the genetics of size inheritance.

The second major problem in rabbit inheritance concerns the possible linkage of the Rex (or Castorrex) character with other known characters. Rex is a short plush-like condition of the fur, inherited as a simple recessive character. Recombinations have been obtained by suitable crosses with all other known genes of the rabbit, and back-crosses between F_1 and the double recessive combinations, which are still in progress, indicate that no linkage exists. This makes Rex the marker of an independent (seventh) chromosome.

Meanwhile, a new rabbit gene has come to light, discovered by Dr. M. Pease of Cambridge University. Yellow fat (due to xanthophyl absorbed from green food) is recessive to ordinary white fat. Pease (*Verh. V. Internat. Kongress f. Vererbungswiss.*) found it to occur only in colored individuals, never in albinos of his colony, and concluded that it was closely linked with the color factor. This conclusion I can confirm. In the course of our embryological studies we have found yellow-fat rabbits in colored, chinchilla and ordinary albino individuals. Yellow fat is recessive in

crosses as stated by Pease. In a cross involving chinchilla (an albino allelomorph) and yellow fat, the 3 chinchilla and 2 albino young of a back-cross litter had yellow fat, whereas the 3 fully colored young had white fat. No cross-overs were observed in this litter, but there can be no doubt that they do occur, in view of the distribution of yellow fat in our colony. Since the color gene is linked with the chocolate gene, no doubt it will be found, as remarked by Pease, that yellow fat is also linked with chocolate. This gives us three linked genes in each of two different chromosomes in the rabbit with which to work.

In mice, Mr. George Snell has been studying a linkage reported in Year Book No. 26 as discovered by Dr. Gates, between short ear and dilution. Gates observed no cross-over in some 1,200 tests. We set out last September to discover whether or not the linkage is complete. After a few hundred tests, we had the good fortune to discover a cross-over, an F_2 dilute, long-eared individual, heterozygous for short-ear. From the progeny of this animal a number of double recessive (short-eared dilute) individuals have been obtained, and we shall be ready soon to carry out the necessary back-cross tests on a large scale, so as to determine with some accuracy how close the linkage is in units of Morgan.

Two new interesting mouse genes have recently been added to our genetic material, (1) *hairless*, a recessive gene, examples of which we owe to the kindness of Dr. L. C. Dunn, and (2) *half-naked*, a dominant gene discovered by Dr. Lebidinsky of Riga, Latvia, who kindly sent us a stock with the generous aid of Dr. H. Nachtsheim of Berlin, who received and forwarded them to us by Dr. Schratz, who was on his way to America to work at the Desert Laboratory, Tucson. These two mutations have similar somatic expression, but in different degree. The young acquire a first coat of hair and then lose it—completely, in the case of homozygous individuals; partially, only, in the case of heterozygous half-naked individuals. The half-naked gene is practically a lethal, as homozygotes are very feeble and usually perish. Hairless is completely recessive and not lethal, apparently, although homozygous females are said to be sterile. We shall cross the two varieties in various ways to see what are their linkage relations to each other and to other genes.

Dr. Pincus and I have recently completed an investigation which has been in progress for several years, involving a reexamination of the selection question in relation to the hooded pattern of rats. We took advantage, for this purpose, of the long series of inbreeding experiments of Dr. Helen Dean King, who has inbred albino rats, brother with sister, for more than sixty generations. This should render them theoretically completely homozygous. Miss King kindly supplied us with some of her inbred rats. We undertook to make visible the hooded pattern carried by this inbred race by introducing the color factor from another race. A suitable mating accomplished this purpose, but also introduced other possible modifying genes. To eliminate these, we make a series of 10 back-crosses to the pure King race, retaining always only the colored young. By this procedure we should theoretically have a colored race, substantially as homozygous as the King race itself for all genes except the color gene and others closely linked with it.

In fact, we found that the variability in the hooded pattern declined to a minimum by the fifth back-cross generation, and thereafter was practically stationary, indicating genetic uniformity. We did, however, observe the occurrence of one marked minus mutation in the inbred race, and it is quite probable that other less marked mutations occurred which we were unable to detect. We conclude that the probable occurrence of mutations of a minor character in inbred lines, and with equal probability in lines not inbred, puts decided limitations on the applicability of the pure line idea, and shows how mass selection may be effective in modifying characters even when they are seemingly monofactorial.

Harris, J. Arthur, University of Minnesota, Minneapolis, Minnesota.
Application of mathematical methods to biological problems. (For previous reports see Year Books Nos. 24-26.)

This statement of progress, of papers published or practically completed for press during the year, and of new methods of application of analytical methods to biological data may be brief, since the program of work has been fully outlined in previous reports.¹ The results of some of the investigations have been more fully described elsewhere.²

I. Physicochemical Properties of Plant-Tissue Fluids

As during the past eight years these studies have involved two inter-related lines of work: (a) The investigation of the tissue fluid properties of plants as a factor determining the geographic distribution of native vegetation and (b) the intensive investigation of the tissue fluids of certain agricultural species which are differentiated into a number of varieties particularly suited to physiological and genetic research under reasonably controlled experimental conditions.

Field studies of the physicochemical properties of the tissue fluids of plants growing under the highly varied conditions of altitude, topography, insolation, temperature, atmospheric moisture and soil aridity and salinity of the desert and mountainous region of the western United States, particularly in Utah, Arizona and Washington, were continued during the summer of 1927 with the assistance of David R. Briggs, Charles W. Crane, J. Arthur Harris jr., Alanson Lay Harris, Wm. M. Martin, John W. Moore, Truman A. Pascoe and Vernon Young.

Because of the wealth of morphologically and physiologically differentiated varieties, because of the possibility of intra-specific and inter-specific hybridization, because of a relatively wide tolerance of environmental conditions, because of the large size of the individual plants, which makes possible the determination of a series of constants on the same individual, and because of favorable technical properties of the tissues, *Gossypium* has proved highly desirable for intensive experimental studies. These are largely long-time genetic experiments on the behavior of such physico-

¹ J. Arthur Harris. *The application of mathematical methods to biological problems.* Year Book No. 24, 278-281, 1925; No. 25, 293-304, 1926, No. 26, 273-379, 1927.

² J. Arthur Harris. *Activities of the Department of Botany, University of Minnesota.* Pages 1-68, Minneapolis, 1926.

chemical properties as osmotic concentration, specific electrical conductivity, chloride and sulphate content, and hydrogen-ion concentration in hybridization, for which a report must be deferred to a later date.

In studies cited in earlier reports, attention was devoted primarily to the rigid biometric proof of the differentiation of varieties or species with respect to the various physicochemical properties of the tissue fluids.¹ Data are now sufficiently numerous so that a consideration of the relative differentiation with respect to specific properties is possible. In a study now practically completed,² it has been shown that the differentiation of the Egyptian and Upland types with respect to chloride content is greater than that with respect to total solutes as measured in terms of osmotic concentration, or of ironized solutes as measured in terms of specific electrical conductivity.

In an investigation reviewed in an earlier report (Year Book No. 26, 274, 1927) it was shown that the relationship between the salinity of the soil and the tissue-fluid properties may be measured in terms of the correlation between the electrical resistance of the soil mass and the freezing-point depression, specific electrical conductivity, and chloride content of the plant tissue fluids. Further studies, based on the concentration of specific ions of the soil (chlorides and sulphates) as well as on the electrical conductivity of the soil mass, are practically ready for publication.³

With the cooperation of Dr. John H. Martin, work has been continued on the tissue fluids of a number of the botanically highly differentiated varieties of *Sorghum*.

A short series of data on the tissue fluids of sugar cane, as grown in the Hawaiian Islands,⁴ has been considered in their possible relationship to the drought resistance of the varieties.⁵

II. Application of Biometric Methods to Agronomic Problems

Work on the development of an adequate statistical technique for dealing with the series of problems presented by the data of plot tests and other cultural experiments as conducted in agronomic, genetic and physiological experimentation, has been continued along the lines indicated in earlier reports.

A second study of the permanence of the differences in the plots of the experimental field has appeared.⁶

Several investigations on the application of biometric methods to the theoretically and economically important problem of seedling stand,

¹ J. Arthur Harris. *Physiological differences in varieties*. Jour. Hered., vol. 18, 277-279, fig., 1927.

² J. Arthur Harris, Wm. M. Martin, Ivan D. Jones and Harold M. Barnett. *The relative differentiation of the Egyptian and Upland types of cotton with respect to certain physicochemical properties of their leaf tissue fluids*.

³ J. Arthur Harris and Truman A. Pascoe. *Further studies on the relationship between the concentration of the soil solution and the physicochemical properties of the leaf tissue fluids of cotton*.

⁴ J. Arthur Harris and H. Atherton Lee. *The properties of the tissue fluids of sugar cane in their possible relation to drought resistance*.

⁵ J. Arthur Harris and H. Atherton Lee. *Possible chemical criteria of drought resistant varieties of sugar cane*.

⁶ J. Arthur Harris and C. S. Scofield. *Further studies on the permanence of differences in the plots of an experimental field*. Jour. Agr. Res., vol. 36, 15-40, fig. 1-6, 1928.

reviewed in the preceding report (Year Book No. 26, 275-277), are now in press or practically ready for publication. These include papers on the distribution of seedling stand over the experimental surface,¹ on the application of Pearson's equivalent probability r to the expression of the deviation of observed frequency distributions of seedling stand from the theoretical point-binomial distribution in terms of the correlation scale,² on the application of intra-class and inter-class equivalent probability correlation coefficients to the problem of the influence of substratum heterogeneity on seedling stand,³ on criteria of the differentiation of varieties or of experimental areas with respect to their capacity for the production of seedling stand,⁴ and on a possible relationship between soil salinity and seedling stand in *Gossypium*.⁵

In view of the fact that this latter study indicates a positive correlation between soil salinity and seedling stand, it has seemed desirable to determine the correlation between some functional characters of the plant and soil salinity. A first study of the relationship between soil salinity and flowering date⁶ indicates negative relationships, i.e., a retarding of the date of flowering on more saline areas.

A general discussion of the service of mathematics in the solution of some of the problems of agronomy has appeared.⁷

III. Fertility and Fecundity in the Domestic Fowl

Papers on the differential egg production associated with death before the end of the first laying year in the domestic fowl, cited and briefly reviewed in the preceding report (Year Book No. 26, 278, 1927), have been extended.

Application of Pearson's double χ^2 method to the problem of the differential egg production of birds which survive throughout a given period and of those which die before the end of the period⁸ has fully confirmed and materially extended the results obtained by the use of other methods of comparison. Since the egg production of the two classes of birds is differentiated with respect to both mean and variability, a test which compares

¹ J. Arthur Harris, George J. Harrison and F. M. Wadley. *Illustrations of the application of a criterion of the deviation of an observed from a random distribution to the problem of seedling stand in Sea Island, Egyptian and Upland cotton*. Jour. Agr. Res., vol. 36, 608-614, figs. 1-3, 1928.

² J. Arthur Harris and Marie M. Ness. *On the applicability of Pearson's equivalent probability r method to the problem of seedling mortality in Sea Island, Egyptian and Upland cotton*. Jour. Agr. Res., vol. 36, 615-623, 1928.

³ J. Arthur Harris and Marie M. Ness. *Further applications of Pearson's equivalent probability r method to seedling stand in Sea Island, Egyptian and Upland cotton*.

⁴ J. Arthur Harris, George J. Harrison and Edna K. Lockwood. *A criterion of the differentiation of varieties, or of the differentiation of experimental areas, with respect to capacity for the production of seedling stand in Sea Island, Egyptian and Upland cotton*. Jour. Agr. Res.

⁵ J. Arthur Harris. *On a possible relationship between soil salinity and stand in cotton*. Jour. Agr. Res.

⁶ J. Arthur Harris. *The correlation between soil salinity and flowering date in cotton*. Jour. Agr. Res.

⁷ J. Arthur Harris. *Mathematics in the service of agronomy*. Jour. Amer. Soc. Agron., vol. 20, 443-454, 1928.

⁸ J. Arthur Harris and Donald C. Boughton. *An alternative criterion of the differentiation of birds which die antecedent to a given period from those which survive throughout the year*. Amer. Nat.

the frequency distributions as a whole is more rigorous than one based on single constants, such as means, standard deviations and coefficients of variation. The contribution of special classes to χ^2 is discussed, and the changes of the magnitudes of χ^2 with the progress of seasonal egg production and mortality are discussed, and the broader biological bearings of the results are indicated. The investigations have also been extended to the problem of the differentiation of breeds of fowl with respect to mortality.¹

A number of investigations, reported in earlier volumes of this Year Book, have been devoted to the problem of the correlation between the physiological activity of the organism as shown by ovulation records at various periods of time. Such studies have a theoretical interest in their bearing on the general biological problem of the physiology of reproduction. In the case of many organisms, they have an economic importance because of the fact that it is possible to pass from measures of interrelationship in terms of a universally comparable scale to measures of interrelationship in terms of regression or prediction equations. It has already been shown that such equations may be utilized for the very exact prediction of the average future egg production of groups of birds for which the ovulation records of limited periods of time are available.

Such work has in the past been limited to periods of time no longer than a single year. In a paper now practically ready for publication² the problem of the correlation between monthly and biennial egg production has been considered.

The correlations between the production of the individual months and the total production of the first two laying years have been shown to be of a substantial order of magnitude. While there are evidences of non-linearity in the regression equations, the availability of larger series of data should make possible the calculation of suitable equations for the prediction of the egg records of periods longer than a single year.

In earlier reports it has been shown that the time of beginning and cessation of laying activity in the first and second laying years of the bird's life are not independent variables, but are correlated. These results at once raise the question as to the relationship between these time variables and the egg-laying activity of the organism in the periods over which ovulation extends.

A detailed investigation of the correlation between the time of beginning and cessation of laying on the one hand and the monthly and annual egg production of both the first and second years on the other is now practically completed.³ In this it is shown that there is in general a measurable correlation between the time of beginning and cessation of laying and egg production during the periods of laying activity. Birds which begin egg production late in the laying year, and birds which cease laying early in the

¹ J. Arthur Harris and D. C. Boughton. *The death rates of three standard breeds of fowl*. Poultry Sci., vol. 7, 120-131, figs., 1928.

² J. Arthur Harris. *A first study of the correlation between monthly and biennial egg production in the domestic fowl*.

³ J. Arthur Harris. *A first study of the relationship between the time of beginning and the time of cessation of laying and the egg production of various periods in the domestic fowl*.

year, show in general lower egg records during the periods of activity than do those which have the egg production extended over a longer period of time. The bearing of these results on various physiological and genetic problems is discussed.

IV. Variation and Correlation in the Newborn Infant of Various Nationalities

These investigations have been continued along the lines indicated in some detail in earlier reports.

V. Biometric Methods and Miscellanea

A paper on a limitation in the applicability of the contingency coefficient (Year Book No. 26, 279, 1927) has appeared.¹ Further limitations of the contingency methods are under investigation. The danger of relying on the conventional formula for the probable error of the standard deviation in cases in which critical comparisons of variability are to be made has been emphasized.² An alternative routine of calculating the product moment correlation coefficient, which has practical advantages in certain cases and serves to show the flexibility of the correlation method, has been given.³ An extension of the method of intra-class and inter-class correlation to include Pearson's concept of the equivalent probability correlation coefficient has been proposed.⁴

In the application of mathematical methods to biological problems the assumption has too generally been made that the measurements are sufficiently accurate, so that only the probable errors of random sampling require consideration in the interpretation of the statistical constants. In many cases this ideal condition is not realized. In more refined biological investigations it will ultimately be necessary to take into account the systematic and random errors of measurement in the interpretation of the final results.

Considerable attention has been given to this problem during the year. A paper on the influence of errors of measurement on biometric constants is in preparation.⁵ Such methods may also find application in fields of chemical research in which comparative studies must be made of wide series of data due to a number of collaborators.⁶ Special application of certain of these formulæ has been made to the testing of the validity of certain analytical methods used by cereal chemists.⁷

¹ J. Arthur Harris and Alan E. Treloar. *On a limitation in the applicability of the contingency coefficient*. Jour. Amer. Stat. Ass., vol. 22, 460-472, 1927.

² J. Arthur Harris and Marie M. Ness. *A note on the probable error of the standard deviation*. Jour. Amer. Stat. Assoc., vol. 23, 178-179, 1928.

³ J. Arthur Harris. *An alternative method of determining correlation coefficients from correlation surfaces*. Amer. Nat.

⁴ J. Arthur Harris and Marie M. Ness. *Determinations of intra-class and inter-class equivalent probability correlation coefficients from the frequency distributions or the moments of the alternative categories*.

⁵ J. Arthur Harris. *The influence of errors of measurement on biometric constants*.

⁶ J. Arthur Harris and Alan E. Treloar. *On the systematic and non-systematic errors of analytical results*.

⁷ A. E. Treloar and J. Arthur Harris. *Tests of the validity of methods used by cereal chemists*. Cereal Chemistry.

Up to the present time biometric methods have been little used in ecological work. Attention has been called to the advantages of certain of these methods in the comparison of the physical factors of habitats.¹

Two addresses on the application of mathematical methods in biology² and medicine³ have been published.

Mann, Albert, Washington, District of Columbia. *Continuation of investigation and preparations for publication of results of work on Diatomaceæ.* (For previous reports see Year Books Nos. 18-26).

This general summary of diatom research carried on during the past year contains few details because most of the investigations are of necessity a repetition of items mentioned in previous reports or a continuation of larger lines carried forward. The following facts, however, give the general scope of work accomplished:

A systematic arranging of all diatom specimens is being made for easier reference. This includes several thousand slides left by will to the writer by the late Alvey A. Adee, a considerable portion of which had to be identified.

The investigation of a belated addition to the marine diatom material collected by the Australasian and the Shackleton Antarctic Expeditions. Although this has delayed the completion of a report, it has considerably added to the known and new species discovered in the Antarctic.

Among other investigations carried over from last year are the diatoms of the Laysan Islands and those collected by the Arcturus Expedition.

A general study has been made of the diatom floras of several lakes in the State of New York as a contribution to a report on their biology, now being prepared by a state committee created for that purpose.

Considerable time during this year has been reluctantly given to preparing reviews of new diatom literature at the request of the committee in charge of the publication of "Biological Abstracts."

The usual large number of outside requests for an examination and report upon diatom material, chiefly fossil earths, has been received. This important item in laboratory service has been given careful attention.

Field work, in addition to the annual collecting and study of marine diatoms found at Dry Tortugas Florida, again carried on this year, has been extended by two new lines of research: First, collecting was done along the west coast of Florida and at Key West, by which a comparison can be drawn between the summer species usually growing in the Gulf of Mexico and those found to exist in the biologically peculiar waters in the vicinity of the Dry Tortugas laboratory. Second, an experiment has been started to determine the actual summer diatom flora in the neighborhood of the laboratory. Specimens secured by dredging, and to some extent by plankton collecting, undoubtedly contain many species not at all characteristic of the diatom flora dominant at the time of collection. This is due

¹ J. Arthur Harris, John Zuenzel and W. S. Cooper. *On the comparison of the physical factors of habitats.* Ecology.

² J. Arthur Harris. *Mathematics in biology.* Sci. Mo.

³ J. Arthur Harris. *The appeal of the problem of disease to the biometrician.* Jour.-Lancet, vol. 47, 191-195, 1927.

to the persistence of diatom specimens by reason of their imperishable structure, which creates a source of error not commonly affecting the study of other biological gatherings. To secure accurate information in this respect a large number of square, unglazed tiles, with red floats attached to mark their location, were placed at different localities. After two weeks they were taken up and the diatom deposit scraped off and preserved. The tiles were then reset and the collecting will be repeated at the close of the laboratory season. By a study of the samples thus secured an authentic list of the actual summer species growing at Dry Tortugas should be obtained.

The annual work at Woods Hole, Massachusetts, has been carried forward this year, covering about seven weeks. An experiment, begun two years ago, of "seeding" barren areas of the coast with diatoms (and their related organisms) obtained from fertile localities has been continued this year. This is an attempt to test out the possibility of extending the feeding grounds of migratory fishes into hitherto barren tracts of coast. It offers at least the possibility of discovering a new and valuable aid to marine and inland fish culture. Collections in the seeded areas are made each year at the same spots and on the same dates; and a study of these is expected to show whether or not a more abundant diatom flora (and its accompanying fauna) is being built up in those barren tracts of the coast selected for the experiment.

In connection with the work at Woods Hole, attention this year has been given to the diatoms of Cape Cod Bay, the waters of which are much more influenced by Arctic diatom migrations than those of Woods Hole and Vineyard Sound.

The productiveness of the laboratory in strictly scientific research is materially less than it should be because of the time required to keep up those merely clerical duties demanded by work of this character.

Morgan, T. H., A. H. Sturtevant and C. B. Bridges, California Institute of Technology, Pasadena, California. *The constitution of the germinal material in relation to heredity.* (For previous reports see Year Books Nos. 15-26.)

It was reported in Year Book No. 24 that *D. simulans* females homozygous for the third-chromosome recessive eye-color claret gave anomalous results, including a high frequency both of non-disjunction and of elimination during cleavage divisions, for chromosomes I and IV. A series of gynandromorphs produced by such mothers has been subjected to statistical study, from which it has been possible to deduce some information as to the cell-lineage of the *Drosophila* embryo, and also as to the developmental relations of the imaginal discs of the larva. These results are now ready for publication. Mr. T. Y. Chen, working in our laboratory, has completed a direct study of the imaginal discs, using the methods of dissection and serial sections. With these two series of observations, our knowledge of the development of *Drosophila* becomes much more precise and satisfactory.

The claret type of *D. simulans* gives rise at times (chiefly, or perhaps exclusively, when females heterozygous for claret are used) to another type

of mosaic, that can not be explained by elimination of chromosomes or by the occurrence of eggs with two separate nuclei. These mosaics are still being studied, but the following relations are already clear: (1) One type of tissue includes most of the fly, the second type being present only as a portion of the head—usually only a few facets in one eye. (2) The small region practically always shows all the dominant characters present in the mother. (3) If the father was heterozygous, the two kinds of tissue receive the same factor from him (i.e., only a single sperm fertilizes the egg). (4) The two kinds of tissue may differ with respect to chromosomes I, II or III, or both I and III, or II and III (probably any combination—the others have not been tested). These and other facts make it seem probable that these mosaics result from a fusion of the three fused polar bodies (or perhaps occasionally only one or two of them) with a cleavage nucleus, the resulting pentaploid nucleus sometimes giving rise to a portion of the surface of the head.

It has been shown that the X, Y, II and III chromosomes of *D. simulans* have genes that correspond to those present in *D. melanogaster*, and in no case has a corresponding gene been found to lie in one chromosome in one species and in another chromosome in the second species. During the past year this parallelism has been still further extended by finding a corresponding gene in chromosome IV. A dominant, Minute-IV, closely resembles the one previously known in *melanogaster* (less extreme in appearance and sterility than the Diminished, or haplo-IV, types that have been cytologically demonstrated in both species). *D. simulans* Minute-IV has been shown to segregate independently (in males) of sex, polychaete (II-chromosome), and scarlet (III-chromosome). It and the Minute-IV of *melanogaster* have both been shown to be allelomorphic to (deficiencies for ?) the *melanogaster* fourth-chromosome recessive rotated-abdomen (received from Professor S. Tschetverikov). The proof is thus complete that the two species have similar material in each of the chromosomes.

Non-disjunction of the X chromosome has been found modifiable by agencies in chromosomes other than the X. The strain used in these tests is descended from the original strain of "high non-disjunction." At present it gives about 12 per cent of exceptions. As reported last year, the third-chromosome combination known as Df2C acts as a dominant reducer of the amount of non-disjunction of the X. The presence of Df2C reduces the percentage of exceptions from about 12 to about 2 per cent. The effect has been retested this year and confirmed. The full formula of the Df2C chromosome is: CIIIL Payne, lethal in left limb, Deformed eye, CIIIR Payne, lethal in right limb. Analysis of the Df2C chromosome was made to determine the locus of the suppressor. The dominant character Df was found not to be responsible, both by testing emergent Df chromosomes and by testing the effect of Df from other stocks, including the stock that had been the source of Df in making the Df2C combination. The right end of the Df2C chromosome was replaced by a new right end from the claret stock. The Df2C ca chromosome was found to have retained the suppressor. But removal of the whole right limb removed the suppressor. The source of this right limb containing the suppressor was known, and

tests of the source stock showed that the suppressor was present in it. That stock had been derived from another stock given us many years ago by Dr. F. Payne. The original Payne chromosome combination was still on hand and was found to give the suppressing action. Because of the low amount of crossing-over in the presence of CIIRP, further analysis of the right limb has not been completed.

Other suppressors of crossing-over in the right limb have been tested and seem to give some effect, that is, a percentage of non-disjunction intermediate between the standard "high" and the low given by CIIRP suppressor. But the high variability of the process of non-disjunction makes it necessary to test this relation more adequately. One second chromosome of the high non-disjunction strain carries crossing-over suppressors in the right and in the left limb, but apparently without effect upon the percentage of exceptions. Likewise the crossing-over suppressors connected with Curly have no effect. On *a priori* grounds it would seem that a crossing-over suppressor in another chromosome should have no effect upon non-disjunction of the X, or if an effect, then an increase in the percentage of exceptions through interference with the process of synapsis and disjunction.

The Df2C combination had been put together to serve in the same manner as the natural combination "Curly" serves for the second chromosome, namely, to carry a crossing-over suppressor for each limb and a dominant marker of the presence of that chromosome. The lethals that were also present in the Df2C chromosome would eliminate from any homozygous stock made by use of Df2C the few crossovers that would occur. Most of these crossovers would occur in the right limb of the Df2C chromosome. This right end was further guarded by the addition of claret to give the Df2C ca chromosome mentioned above. Any surviving fly homozygous for the right end would now be detectable by the manifestation of the character claret and could be discarded. An accurate knowledge of the amount and the distribution of the crossing-over that takes place in the presence of Df2C ca was obtained by backcross tests to the extent of 15,000 flies. The total amount of crossing-over was found to be 2.91 per cent, distributed as follows: ru to h, 0; h-th, 0; th-st, 0; st-Df, 0.61; Df-cu, 1.32; cu-sr, 0.35; sr-e⁺, 0; e⁺-ca, 0.63. The total of 2.91 per cent for the length of the third-chromosome is the lowest amount of crossing-over so far obtained, and hence the Df2C ca stock is the most serviceable third-chromosome stock we are at present able to put together.

In the same way that the right limb of the Df2C ca chromosome was guarded, the right limb of the Curly chromosome is now guarded by the addition of speck. Tests, to the number of 15,000 flies, showed that the Cy sp combination gave crossing-over throughout the second chromosome to the total amount of only 0.505 per cent, with a distribution as follows: Cy to b, 0; b-pr, 0.474; pr-cn, 0.002; cn-L, 0.017; L-sp, 0.012. Most of the crossing-over in the region from cn to sp occurred in the form of double crossovers. This excess of doubles is probably due to the fact that single crossovers within an inverted section give lethal combinations by deficiency or duplication effects. But double crossing-over within the inverted section gives only the normal amount of chromosome and the doubles survive.

The data suggest that the CIIR of the Curly chromosome is an inversion, and that it is extensive enough to include both vestigial and Lobe, with a considerable section to the right of Lobe.

A review of the older cytological material prepared to show the chromosomes that have undergone "translocation," and a study of considerable new material, have cleared up this situation somewhat. The genetic data show that in "Pale translocation" about eight units of the right end of the second chromosome have been detached and have become intercalated in the right limb of the third chromosome.

The older material involved one second chromosome deficient and one third chromosome carrying the duplicating piece. In those preparations inequality in the length of the smaller pair of V-shaped chromosomes was seen clearly, and in the larger pair with some probability. It was much more difficult to decide which of these inequalities represented a chromosome longer than normal and which a chromosome shorter than normal. The probabilities seemed in favor of the deficiency being in the shorter pair and the duplication on the longer pair. The newer material is prepared from flies which genetic tests had shown were heterozygous for the second-chromosome deficiency and *homozygous* for the third-chromosome that bears the duplication. This should be much more diagnostic than the older material, since now only one unequal pair is present while the other pair is equal. The unequal pair must be the second chromosomes. But in the third-chromosomes another type of inequality is present, namely, one arm of the V is longer than the other for both members of the pair. It has not been possible to obtain enough flat clear metaphase plates to make the observational check entirely conclusive, but all plates are in agreement that the unequal pair is the larger pair, with one arm of one member shortened by deficiency, while the equal pair is the shorter V-chromosomes, with each member longer in one limb by a duplication. As in the older material, this inequality in the limbs is more marked in the shorter pair—probably because the section added makes a proportionally greater change in a short chromosome than when subtracted from a long chromosome. This observational check is adequate on the point that both the deficiency and the duplication can be seen in the chromosomes, and makes very probable the identification of the larger pair of Vs, as the bearer of the second group of linked genes and of the smaller pair of Vs as the bearer of the third group of linked genes.

The mutation eosin originally arose as a conversion of white into eosin. There have been one or two probable cases of reversion of eosin to white. Recently a certain case has been found in an eosin male that showed nearly all of the right eye white and about half of the left eye white. This male was crossed to attached-X yellow females and the sons were found to be only white. The reversion had occurred early enough in the embryonic development so that the gonads were entirely descended from the white-bearing tissue that also gave the white patches in the eyes. The mutation eosin has arisen more than once, and at least once directly from the wild-type. Our records are not clear as to whether this eosin which changed to white is the original eosin or one of the later ones.

That at least two of the Minutes are deficiencies has already been reported. It has now been found that Minute-IV, located in the fourth chromosome, is a deficiency for the recessive mutation "abdomen rotatum." The twisted abdomen stock was received from Professor S. Tschetverikov.

From R. L. King we have received the second-chromosome dominant "Bristle." This dominant resembles Stubble closely, that is, has bristles that are sharply truncated instead of long and tapered. Bristle is not lethal when homozygous. The locus of Bristle, according to King, is 0.2 unit to the right of purple. It seems probable that Bristle will displace purple as a representative of that important region near the spindle-fiber attachment, since its sharper classification and its dominance make it more useful.

Mutants to the usual number have been found and located. A few of them are important in giving better control of certain sections of chromosomes.

An attempt has been made to find out whether extensive injury to the eyes of *Drosophila melanogaster* has any influence in increasing the percentage of mutations. The eyes of newly hatched females were touched with the tip of a hot needle. The color of the eye is instantly changed and injury becomes permanent. Within an hour the Malpighian tubules become brilliantly red and can be seen through the ventral body wall. The color is due to the granules in the cells becoming colored. The color lasts for several weeks. Numerous experiments have been made with different mutant eye colors and with the assistance of Dr. Douglas Whitaker the effect of directly injecting materials from the eyes of several mutant types has been studied.

Many of the injured females die without laying eggs, but those that recover receive the male and may produce abundant offspring. Since only the immediate offspring of these females were examined critically, the mutant types expected would be X-chromosome recessives and dominants in any chromosome. A few dominants have appeared in the daughters and several recessives in the sons. Some of the latter are new mutants, others already known or allelomorphic types. These are being studied and their genes located in the chromosomes. Owing to the malformations that also occasionally appeared, it is difficult to accurately determine whether the results do or do not give a percentage of mutants higher than that shown by the same stock without treatment. Before a definite answer can be given, several psychological controls will have to be made, as well as an examination of the differences due to starvation and to conditions of the food. At present, it can only be said that more mutants have been found in the offspring of the burnt eyed flies than in the extensive controls. These mutant characters appear in different parts of the body and not more frequently in the eyes than elsewhere.

Dr. Dobzhansky has made a detailed study of the characteristics of the triploid intersexes. Measurements were made of somatic characteristics, such as length of bristles and wings, and it was found that in most of these features the body proportions of the intersexes were intermediate between females and males. The degree of development of the sexual characteristics, both external and internal, were recorded for a large number of intersexes. It was found that each characteristic of the male type could exist as per-

fectly developed as in the normal male or exhibit any grade of rudimentary development in size, form and complexity. Normally the end of a series was the non-appearance of the given male part—not its gradual transformation into a corresponding female part. The female parts arose *de novo* as fresh out-pushings from the imaginal discs. An exception to this rule was the gonad, which showed all transition stages between a fully developed testis and a typical ovary. Correlation coefficients were calculated, which showed positive correlation between the different male parts and between the different female parts, and negative correlations between the male and the female parts. The seriation in the coefficients of correlation showed quite exactly the order of a given part in stability or, conversely, the value of a given part as an index of the sex grade of the individual. The development of normal pupæ of males and of females was studied to determine the relative times at which the different sexual characters developed and became definitive. It was found that the order of appearance and development of the characters of the male was the same as the order of stability of the male characters of the intersex, while the order of appearance and development of the female characteristics was reversed as compared with the order of stability of the female characteristics of the intersexes. From this it was concluded that the triploid intersexes start development as males and proceed thus to a turning point beyond which the development of all male characters stops and female characters commence to develop. If this point comes late in development an extreme male-type intersex results, if early in development an extreme female-type intersex.

A stock of *Drosophila melanogaster* has been found by L. V. Morgan in which there is an extra fragment of the first or X-chromosome, visible in sections of the metaphase plate. The males carrying the fragment are usually inviable. Males that survive show somatic disturbances and are sterile; the females show by genetic tests that the fragment carries the normal allelomorphs of yellow, achete, scute, and prune (loci at the left end of the X-chromosome) and the normal allelomorphs of fused and bobbed (right-end characters). The fragment does not carry the normal allelomorphs of the tested characters white, facet, echinus, ruby, crossveinless, cut, lozenge, vermilion, garnet or forked. The fragment can be regarded as an X-chromosome with a missing section, "deficiency," extending from a point between the loci for prune and white to a point between the loci for forked and fused, a section of about 60.5 map units. The fragment comprises therefore about 14.5 map units.

Sumner, F. B., Scripps Institution of Oceanography, La Jolla, California.
Continuation of ecological and genetical studies with Peromyscus.

During the year past, work on the *Peromyscus* was carried on under the joint auspices of the Carnegie Institution and the Scripps Institution of Oceanography, and may be summarized as follows: (1) Collection of about 450 living specimens of *Peromyscus* in Florida and Alabama, together with field observations regarding these animals and their environment; (2) rearing most of these mice to full maturity at La Jolla, and using a large number for genetic purposes; (3) preparation of the skeletons of certain earlier series

and the measurement of these; (4) statistical analysis of earlier material, and beginning such analysis with material derived from the last field trip. The labors comprised under the fourth heading probably consumed more time than all the others combined.

The following discussion of results relates chiefly to the field trip. From the commencement of my studies of *Peromyscus*, it was realized by all interested in the matter that one highly important task was the running of a cross-section through the ranges of two contiguous subspecies and the "area of intergradation" between them. For various reasons, this task was continually deferred. In a trip to the southeastern states, which I made during the summer of 1924, what appeared to be an extremely promising case for an investigation of this sort was found. A rather widely distributed mouse, *Peromyscus polionotus polionotus*, having color characters fairly typical for the genus, is represented in the coastal region of northwestern Florida and southern Alabama by a quite distinct race (*P.p. albifrons*), differing from it strikingly in color and some other characters. On an island reef, skirt-ing this part of the Florida coast, is a third race, *leucocephalus*, having paler coloration and more extensive white areas than any wild mouse with which I am acquainted. This island, and the beaches and dunes of the mainland, are of pure white sand.

The interior race, *polionotus*, and the coastal race, *albifrons*, although of strikingly different appearance, have been described as subspecies, rather than separate species, because it was assumed that somewhere their ranges met and that intergradation occurred. Up to last summer, however, a belt of unexplored territory, over a hundred miles in width, intervened between the known ranges of these two forms. This offered a tempting field for exploration. With the assistance of Mr. J. J. Karol, I commenced field work on August 27, 1927, and discontinued trapping on October 23. During this period, we trapped at seven chief stations, or rather groups of closely associated stations, and at several minor ones. These were situated along a very irregular line, between the gulf coast of Florida, near St. Andrews Bay, and the vicinity of Abbeville, in southeastern Alabama. Our automobile mileage during these two months was over 3,300. Our total catch of mice was about 500, of which we sent 436 living specimens of the *Peromyscus polionotus* group to La Jolla.

While the statistical analysis of these later series of animals has not yet been completed, nor colorimetric determinations of the pelages commenced, according to my customary procedure, certain relations, which were already fairly obvious in the field, have been abundantly confirmed by preliminary studies in the laboratory. These relations may be summarized as follows:

With regard to the most obvious characters (those related to pigmentation of pelage), we find, within the area visited, two well-marked geographic races. Throughout a strip about 40 miles in width, in the region explored, occurs the coastal race, *albifrons*, having a pale, buff pelage of much the same shade as many of the rodents of our southwestern deserts. Unlike most of the latter, however, the hairs of the ventral white area are white to their very bases, the dorsal stripe of pigmented hair on the tail is com-

monly vestigial or lacking, and the dorsal surface of the snout is frequently white.

At a point about 40 miles from the coast, this pale race gives place rather abruptly to one which is far more typical of the genus *Peromyscus*. This is of a much darker shade, quite comparable with that of our more familiar white-footed mice of other regions. The dorsal tail stripe is fully developed, and the hair of the ventral area is white at the tips only, being dark at the base. Various regions of the naked skin are likewise more heavily pigmented.

Certain important qualifications are necessary, however, in the foregoing account. Even as regards color characters, throughout this forty-mile strip, *albifrons* is not homogeneous. There is a well-marked gradient of increasing pigmentation shown in several ways as we pass from the coast inland. Likewise, the *polionotus* which we first encounter, after crossing the "zone of intergradation," averages slightly paler than that of the more distant parts of its range. But, all in all, these intra-racial differences are small in comparison with the inter-racial ones, and the transition from one race to the other is abrupt, in comparison with the gradual change to be observed within the territory of each. On the basis of color characters, accordingly, we seem justified in recognizing here two subspecies and only two.

The "area of intergradation" between these two subspecies, at least in the territory explored, is surprisingly narrow. We trapped large and fairly uniform collections of *albifrons* and *polionotus*, respectively, at points not more than 10 miles apart, and it is likely that this distance could have been greatly diminished. In the intervening area, it happened that trapping was somewhat difficult owing to agricultural conditions, but about 45 mice were captured at four points within a few miles of one another. Taking this population as a whole, it resembles *polionotus* much more nearly than *albifrons*. The majority of specimens are quite indistinguishable from "true" *polionotus*, although trapped only 2 or 3 miles from a region infested by *albifrons*. Other specimens resemble in appearance F_1 hybrids between the two races, while a small minority would pass for the darker specimens of *albifrons*.

In judging the foregoing situation two facts must be borne in mind: (1) That *albifrons* and *polionotus* are perfectly fertile *inter se*, as shown by abundant breeding tests, and (2) there is no evident barrier, geographic or ecological, between the ranges of the two types. I am quite aware that a careful ecological study should sooner or later be made here by a competent expert, but after driving through this section, on various roads, for a distance which probably totaled several hundred miles, I feel justified in assuming provisionally that no such barrier exists.

But the situation is even more puzzling than I have thus far described. If we compare the *albifrons* of the immediate vicinity of the coast with the *polionotus* of the interior, we find certain pronounced differences other than those relating to color. The tails and feet of the former average distinctly longer than those of the latter. In my earlier account of this group, based on the collections of 1924, I showed that we had a graded series in regard to both tail and foot length, *leucocephalus* (the island form) having the longest

members and *polionotus* the shortest, with *albifrons* occupying an intermediate position. We thus have a gradient in the length of these parts which corresponds to the geographic gradient and likewise to the gradient in color.

The *albifrons* of the coastal sand-dunes, collected in 1927, greatly surpassed *polionotus* in the length of tail and feet, just as had been observed in 1924, when the *albifrons* collections were limited to the shore line.

But at a distance of less than 20 miles inland (the next of our stations), the tails and feet of the mice (undoubtedly *albifrons* in color characters) had diminished to such an extent that they were even shorter than those of *polionotus*; and this short-tailed, short-footed condition persisted throughout the remainder of the range of *albifrons*, so far as explored by us.

The facts above summarized, together with the results of genetic studies of this group throughout a considerable number of years, point fairly decisively to certain conclusions.

(1) Environment has played some all-important part in the differentiation of these local races. There are definite spatial gradients in respect to certain of the characters, and there are also definite correlations between particular characters and particular types of environment.

(2) It is evident that different characters have undergone genetic changes quite independently of one another, and that such changes have been manifold, even in the origin of two closely related geographic races. Not only is there no correlation between many of the elements of a subspecific complex of characters, but in respect to each single "character" (extensity of the colored pelage, for example), the difference between two nearly related subspecies depends upon numerous, independent factorial changes. My later breeding experiments have given pretty decisive evidence of mendelian segregation, as regards some of the most important subspecific differences, but they have likewise shown that no character difference yet studied is conditioned by a single pair of factors. The "multiple factor" scheme appears to hold throughout.

(3) From the facts discussed in the two preceding paragraphs, it is evident that changes in genetic factors must have been continually accumulated (by selection or otherwise) under the directive influence of the environment. Purely random mutations of genes could not result in progressive modification in a given direction, especially when this last is correlated with known factors of the environment.

(4) It seems plain that our recognizable subspecific characters do not afford a likely basis for natural selection. It is highly improbable that small differences in the length of the tail, feet or ears, or even in the color or extent of the pigmented area of the pelage, are of any survival value in most of the environments which are tenanted by geographic races of mice. On the other hand, it is known that both pigment formation and the length of the appendages are influenced by general metabolic conditions, which, in turn, may result from differences in the activity of the endocrine glands, or from other causes.

(5) The foregoing facts make it probable that the adaptation of each of these subspecies to its special environment, and thus the basis of selec-

tion—if this is the mechanism by which these progressive changes have been brought about—is largely physiological rather than morphological. It is some of these probable differences in the physiological activities of the various subspecies which I hope to be able to measure with suitable apparatus, already purchased in part.

(6) Considerable attention has been devoted to the question: How can a continuous environmental gradient bring about such a relatively abrupt change in a population as that which is encountered in passing from the range of *polionotus* to that of *albifrons*? A discussion of this question must be deferred, however, to a later publication.

The work planned for the coming year comprises: (1) The completion of computations (already far advanced) and the preparation of a report upon genetic studies of the *Peromyscus polionotus* group; (2) preparation and study of the skins and completion of a report upon the results of the 1927 field trip; and (3) the initiation, with the assistance of Mr. H. A. Harris, of studies of subspecific differences in behavior and other physiological characteristics of *Peromyscus*.

Tennent, D. H., Bryn Mawr College, Bryn Mawr, Pennsylvania. *Microscopic investigation of the fixing and staining reactions of substances extracted from the eggs of Echinometra lucunter*. (For previous reports, see Tortugas Laboratory, Year Books Nos. 8, 9, 11, 22, 26.)

In conjunction with the extraction and chemical identification of the alcohol soluble substances in the eggs of the sea-urchin, *Echinometra lucunter*, a study was undertaken of the reaction of these extractives to certain recognized fat and lipid fixatives and stains. It was felt that such an investigation would be of great value in interpreting the nature and significance of the cell inclusions found in eggs preserved for cytological study, and that a correlation between the observations made on isolated and identified substances and the structures found in fixed ovarian tissue would make possible an exact histo-chemical analysis of the *Echinometra* egg during its growth and development. The chemical analyses were made by Dr. D. E. Smith, while the microscopical work was done with the collaboration of Dr. M. S. Gardiner.

The investigation is based on *Echinometra* ovaries obtained at the height of the breeding season in two successive years. The 1926 material was analyzed qualitatively, samples of the extracted substances fixed and the study of their staining reactions begun. The analyses described below are based on three lots of ovaries collected in 1927. Each lot weighed 300 grams, wet weight, and each was preserved and extracted in 1,600 grams of 97.5 per cent alcohol.

After the quantitative determination of fats and phosphatides in each lot separately, the ether soluble portions of the alcoholic extract of the three lots were combined for the study described here.

SEPARATION OF THE ETHEREAL SOLUTION OF TOTAL FATS EXTRACTED

One litre of ethereal solution, representing the ether soluble portion of the alcoholic extract of *Echinometra* ovaries, was evaporated under reduced

pressure to a volume of 200 to 300 c.c. Upon chilling in a mixture of ice and salt, a precipitate formed at once. This precipitate was removed by decantation and centrifugation, dissolved in warm ether, the ethereal solution chilled as before, and the substance, possibly representing the cerebroside fraction of the extracted material, reprecipitated. The supernatant of the original ethereal solution was allowed to stand 15 to 16 hours in the ice and salt mixture, with the result that there was a further precipitation. The second precipitate was similarly dissolved in warm ether, and reprecipitated by chilling. The relatively high solubility of this substance in ether makes it doubtful if this actually represents the cerebroside fraction. Tests for a reducing sugar were not made, but the identification of the substance will be completed.

After this fraction had been wholly removed from the ethereal extract, the cephalin was precipitated by treatment with warm alcohol (98.5 per cent alcohol warmed to 60° C.). The cephalin came down as a dark brown, gummy precipitate, and in addition a little fine white cloud was precipitated.

The material was left standing for some time in the cold, with the result that a good deal of fat crystallized out from the supernatant. These crystals were extracted with warm alcohol, and the cephalin removed from the solution by filtration. The cephalin was dissolved in ether and centrifuged to remove the powdery sediment. This sediment, consisting of traces of white and a very dark-brown powder, may possibly represent the water-soluble pigment, adsorbed by the lipoids. The ethereal solution of cephalin was decanted from the sediment, and the cephalin reprecipitated as a yellow, flocculent substance by treatment with ethyl alcohol warmed to 60° C.

The filtrate from the cephalin, and all the alcohol used in its precipitation, was diluted with ether until the fats remained in solution at room temperature. The solution was then divided into three portions, the clearest of which was treated with saturated alcoholic cadmium chloride solution. A voluminous yellow precipitate of lecithin cadmium chloride came down, which was left under carbon dioxide at room temperature.

The other two portions were filtered through a folded filter washed in 96 per cent alcohol. A very small amount of precipitate was thus obtained, which was dissolved in ether on the filter, and the ethereal solution added to the flask containing the second cephalin precipitate.

The filtrate was now treated with saturated alcoholic cadmium chloride solution, and after standing 24 hours, all three portions were filtered through the same folded filter. The filtrate was absolutely clear, the lecithin cadmium chloride remaining on the filter as a cream-colored precipitate. This was carefully removed from the filter paper and suspended in ether.

After standing two days in the cold under carbon dioxide, the lecithin cadmium chloride was filtered off from the ether, which had now become deep orange-brown in color. The lecithin cadmium chloride was washed five times in dry ether, after which the supernatant remained nearly colorless. The filtrate was freed from excess cadmium chloride by treatment with ammonia in methyl alcohol, and filtered through a folded filter to remove the cadmium hydroxide. The washed precipitate was removed from the ether by centrifuging and treated with dry chloroform, although it was found

impossible to dissolve the precipitate completely, even with the addition of a few drops of methyl alcohol. The cadmium was removed by means of ammonia in methyl alcohol, and the lecithin twice precipitated with acetone. Some of this was dried over phosphorus pentoxide for microscopic study of its fixing and staining reactions.

The cephalin was dissolved in ether, and the ethereal solution was allowed to stand 14 to 16 hours in the cold to allow any "white matter" to settle out. It was then precipitated four times from ethereal solution by warm alcohol (absolute alcohol, warmed to 60° C.) and the precipitate removed by centrifuging. Part of this was dried over phosphorus pentoxide in a vacuum desiccator to be used for microscopic study.

The ethereal solution of fat, from which the lecithin and cephalin were removed, was evaporated under reduced pressure until the odor of ammonia could no longer be detected, and kept in the cold under carbon dioxide.

TABLE 1—*Summary of analytical results, 1927-28*

	Analysis 1		Analysis 2		Analysis 3	
Weight of tissue at Tortugas.....	304.8	gms.	316.6	gms.	304.42	gms.
Dry residue, after extraction....	50.026	gms.	48.238	gms.	46.8621	gms.
Extractives, alcohol soluble, ether insoluble	11.4543	gms.	14.3585	gms.	14.1147	gms.
Weight of fat dissolved in 5 c.c. of ethereal solution of total fat extracted (average of two weighings)	0.2743	gms.	0.2754	gms.	0.2731	gms.
Total fat extracted (volume of ethereal solution 500 c.c.).....	27.43	gms.	27.54	gms.	27.31	gms.
Ether soluble phosphorus in 1 c.c. of ethereal extract of total fats..	0.4398	mgs.	0.4459	mgs.	0.4386	mgs.
Cholesterol in 1 c.c. of ethereal extract of total fats (average of two weighings).....	3.45	mgs.	4.1735	mgs.	5.8685	mgs.
Iodine number, determined on total fat dissolved in 5 c.c. of ethereal solution.....	84.63		85.83		82.59	
	84.50		85.83		82.92	
¹ Iodine number of lecithin fraction.	107.5				82.40	
Iodine number of cephalin fraction.....	46.5					

¹ The iodine numbers of lecithin and of cephalin were determined from the total quantity of these substances obtained from the three analyses.

Samples of the unseparated extract, and of each of its fractions, were sucked or injected into pith, fixed, embedded and sectioned. All the pith that was used was especially prepared by peeling to remove the hard outer layer, and by soaking for twenty-four hours in ether to dissolve any fatty substances which might be present. It was then dried in air twenty-four hours before infiltration. The extractives were emulsified, and were introduced into the pith either by injection with a hypodermic syringe or by suction with an ordinary filter pump. The latter method gave more satisfactory results, as a greater amount of the substance was carried into the

pith cells. Various means of emulsifying the substances were used, which, with the extractives themselves, may be classified as follows:

(1) *Total Fats*—the ether soluble portion of the original alcoholic extract, presumably containing the cerebrosides, phosphatides, cholesterol, cholesterol esters, neutral fats, fatty acids and possibly soaps.

The material obtained from the analysis made in 1927 was dissolved in ether and shaken with distilled water. After it had been drawn into the pith, the ether was evaporated in a current of air, and the pith cut into small pieces and dropped into the fixing agent.

Similar material, obtained from the 1928 analysis, was dissolved in ether, and 2 c.c. of the ethereal solution shaken in a stoppered cylinder with 2 c.c. of distilled water, and then ground in a mortar until the odor of ether was gone. The aqueous emulsion was then sucked into pith for thirty minutes, and the pith fixed.

(2) *Lecithin*—The lecithin fraction of the ethereal extract, twice precipitated with acetone.

The material obtained from the 1927 analysis was shaken with ether, chloroform and water, and sucked into pith; that from the 1928 analysis was ground in a small mortar with distilled water and sucked into pith.

(3) *Cephalin*—The cephalin fraction of the ethereal extract, four times precipitated with warm alcohol.

The two lots (1927 and 1928) received the same treatment as the lecithin fractions.

(4) *Cholesterol and fats*—The remainder of the ethereal extract after the removal of the cerebroside (?), lecithin and cephalin fractions, probably including cholesterol and the cholesterol esters, if any, the fats, fatty acids and soaps. The ethereal solution was ground in a mortar with water, until the odor of ether had disappeared, and sucked into pith.

As a check upon the extracted substances, pith was similarly impregnated with purified commercial cholesterol and lecithin, emulsified with ether, chloroform and water. Control material was also prepared from pith soaked in ether and dried, but unimpregnated with any substance, and from pith into which was drawn a mixture of ether, chloroform and water in similar proportions to those used in making the lipid emulsions.

The two methods of fixation used were those of Champy-Kull (Lee,¹ p. 333) and Ludford's modification of the Mann-Kopsch method² (Lee, p. 345). After fixation, the material was dehydrated and embedded in 50° to 52° paraffin, and sectioned in the usual way. Where stains were used, the method followed was that of Champy-Kull, that is, staining with acid fuchsin, thionin and aurantia after treatment for 15 to 30 seconds with 1 per cent potassium permanganate and 5 per cent oxalic acid. Where extraction of osmicated substances was indicated, the extraction was made with turpentine whose efficacy had previously been tested with mutton fat

¹ Bolles Lee. *The microtome's vade mecum*. 9th edition, 1928.

² The designation of this method as that of Mann-Kopsch is regarded by Bowen ('28) as incorrect; he proposes that it be called the Weigl method, since to Weigl is due the essential point which differentiates it from all other methods.

³ R. H. Bowen. *The methods for the demonstration of the Golgi apparatus III. Methods of osmic impregnation*. Anat. Rec., vol. 39, 1928.

fixed by the Mann-Kopsch method. It was found in the case of neutral fats that the action of turpentine was that of a solvent for the osmicated substance, although this was not true for other substances blackened by the action of osmium tetroxide.

In addition to that fixed in the pith, small amounts of the extracted substances were used for smear preparations, and for observations with Nile blue sulphate, Scharlach R, Sudan III, neutral red and Janus green. The lecithin and cephalin used for this purpose were kept in vials in a desiccator, while the cholesterol and fat fraction was kept in ethereal solution in a sealed glass-stoppered bottle.

(1) *Total Fats*—A small amount of the ethereal solution was shaken with water, drawn into pith and fixed. The results of the observations on this material are presented in Table 2.

TABLE 2

*Mann-Kopsch**Champy-Kull*

1927

1. Slides not extracted, not stained:

Angular colorless or yellowish structures, some with a blackened rim and some without.

Some large masses, with yellow, almost crystalline groundwork, and linear aggregates of fine black granules twisted over the surface.

Very rarely, isolated black granules.

Some blackened spherules.

Some unblackened crystalline (?) needles and plates.

In some cases, superficial blackening of crystalline (?) forms.

2. Slides extracted in turpentine, not stained:

20 minutes in turpentine. Very little, if any, extraction.

20 minutes in turpentine.

No blackened spherules.

Needle-like and angular crystalline (?) forms evident, some still retaining a slight amount of superficial blackening.

3. Slides not extracted, stained:

Oval or circular structures, stained red, some of which contain fine blackened particles.

No crystalline (?) forms.

Spherical and irregular dark red masses, in which the fuchsin stain has been superposed on osmic blackening.

No crystalline (?) forms.

Some spherules, staining clearly red with no indication of previous blackening.

4. Slides extracted in turpentine, stained:

25 minutes in turpentine.

No staining evident.

Angular yellowish structures present.

20 minutes in turpentine.

Unstained crystalline structures again apparent.

1928

1. Slides not extracted, not stained:

Very uniform conformation of gray masses, enclosed by partial or complete black rims.

Aggregates of apparently empty vesicles, with deeply blackened walls.

Irregular blackened masses, some of which are deep greenish black, and some a lighter gray. Some are homogeneously blackened; others both of the greater and lesser degree of blackening, have more deeply blackened peripheral regions, giving the appearance of a beaded black rim.

2. Slides extracted in turpentine, not stained:

2 hours in turpentine.

Slight amount of extraction. Structures with homogeneous centers and beaded black rims.

2.5 hours in turpentine.

The black and gray masses are removed, leaving groups of black rings of unevenly distributed substance.

3. Slides not extracted, stained:

Large black masses taking fuchsin stain over osmic impregnation.

No evidence in this series of slides of the gray rimmed structures.

Fuchsin stain superposed on black substance of irregular masses.

Beaded black rings enclosing gray substance.

Structures similar to the blackened rings but staining red.

Small clear red spherules.

4. Extracted in turpentine, stained:

1.5 hours in turpentine.

Gray substance which takes no stain, and black rods in random distribution.

Red droplets of varying size.

Large dark masses gone.

Red rings gone.

Dark and light red spherules.

The disparity between these two sets of observations is probably to be explained by the difference in treatment of the 1927 and 1928 material (see page 342). In the former, the solvent was withdrawn from the pith before fixation, so that the substances were not actually in solution when acted upon by the reagent, while in the material obtained from the 1928 analysis, the dissolved fats and lipoids represented the disperse phase of an emulsion whose continuous phase was immediately replaced by the fixative.

A complete analysis of the substances contained in the total fat solution can not be made until some of the material is available for work with dyes and reagents specific for certain substances. The pith material is not wholly favorable as it is highly probable that there is a kind of fractional infiltration of the extractives into the pith cells, so that no two slides are entirely comparable in the material, or condition of the material, represented in them. It is, however, evident that at least five different substances are contained in the extract. The presence of neutral fat is indicated by the blackened masses which are removed by turpentine, leaving no stainable residue. The apparently crystalline structures, which form a substrate for the fine blackened granules, is identified as lecithin, partly from the fact that these structures can be shown to be those which give rise to the red spheres in stained preparations, and partly from observations made on the lecithin fraction and on purified commercial lecithin. An absolute distinction between cholesterol and fatty acid has not been made, nor have any cholesterol esters been identified.

(2) (1) *Fat and cholesterol fraction* (total fat minus cerebroside, cephalin and lecithin fractions)—Aqueous emulsion was sucked into prepared pith. The pith was then fixed, embedded and sectioned. The results of the observations are presented in Table 3.

TABLE 3

<i>Mann-Kopsch</i>	<i>Champy-Kull</i>
1. Slides not extracted, not stained:	
All droplets very black.	All droplets very black.
2. Slides extracted in turpentine, not stained:	
Short extraction leaves a grayish-brown border containing fine black granules, the center of the droplet remaining solid black.	Sections of droplets show a dark, not black, rim. Center gray; granules, slightly darker than the gray matrix, scattered through the central substance.
3. Slides not extracted, stained:	
Droplets very black; no evidence of stain.	Very black droplets.
4. Slides extracted in turpentine, stained:	
Same as extracted, unstained (2).	Extracted 28 hours; dark rim, gray centers, small holes in centers, no granules. Extracted 48 hours; rims thinner than in 28 hours extraction.

The facts may be summarized as follows: In the Mann-Kopsch fixation the droplets are deeply blackened by osmic acid; they are not stained by fuchsin-thionin-aurantia; their granules and their centers are resistant to extraction. In the Champy-Kull fixation the blackening is less deep than in Mann-Kopsch; the droplets are not stained by fuchsin-thionin-aurantia; their rims are more resistant than their centers to extraction; their granules are completely extracted (dissolved) in turpentine.

(II) *Aqueous emulsion made from residue remaining after drying ethereal solution over CaCl_2 .* Drops of the emulsion fixed on slides in Mann-Kopsch and in Champy-Kull. The results are presented in Table 4.

TABLE 4

<i>Mann-Kopsch</i>	<i>Champy-Kull</i>
1. Slides extracted in turpentine, unstained	
Extracted 24 hours. Gray matrix with central black mass, or with small black granules. Peripheral "husk-like" edge probably the closely stuck rim of the drop from which the center was lifting away.	Extracted 20 minutes. Clear matrix with flocculent grayish masses; some with black granules or with granular filaments; some vesicles with a black rim.
2. Slides extracted in turpentine, stained:	
Extracted 24 hours. Same as unstained.	Extracted 20 minutes. Same as unstained.

The results may be summarized thus: Drops of fat and cholesterol are deeply blackened by both Mann-Kopsch and Champy-Kull fixation. The Mann-Kopsch material is resistant to extraction (solution); the Champy-Kull material is readily extracted (dissolved). The material does not stain with fuchsin-thionin-aurantia.

(III) *Aqueous emulsion made from the residue remaining after drying the ethereal solution over CaCl_2 , stained with vital dyes:*

(1) Stained with 1:40,000 neutral red. The orange-colored droplets, varying in size from macroscopic down to almost invisible particles, which were distributed through the continuous phase of water, all stained a clear red. Included in many of the droplets were smaller ones which stained very deeply. A viscid material in scattered, irregular masses or in small spherules which attached themselves to the surface of the stained droplets, forming an envelope about them, stained lightly. Numerous air bubbles enclosed by a film of stained fat were also present.

(2) Stained with 1:20,000 and 1:40,000 Janus green. The results were essentially the same as those with neutral red. The large yellow droplets did not become as blue as the smaller, probably because of their size. The smaller blue droplets, down to the limits of visibility with the 2 mm. immersion objective, were in Brownian movement. The same four types of material seen in the neutral red preparations were evident.

(IV) *Tests of the emulsion made with Nile blue sulphate, Scharlach R and Sudan III:*

(1) Nile blue sulphate stained all of the globules blue. Lorrain Smith ('07)¹ found that Nile blue stains neutral fats red and fatty acids blue. There were no red globules following the Nile blue sulphate stain. Scharlach R and Sudan III stained similar globules red, but not intensely so. The evidence therefore suggests that the globules are fatty acids rather than neutral fats.

[That this evidence is not conclusive is indicated by tests made with Nile blue sulphate on known mixtures of triolein and oleic acid after this report was written. Our tests show that while triolein, taken separately, is stained red and oleic acid blue by Nile blue sulphate, mixtures containing a very small amount of oleic acid are stained blue by this stain. The blue staining therefore can not be regarded as necessarily indicating an absence of neutral fat.]

The ethereal solution of fats and cholesterol was evaporated to dryness over CaCl_2 , dissolved in chloroform, evaporated and redissolved twice. The dried residue from this solution was washed quickly with warm alcohol in order to separate the fatty material from the sodium sulphate that had been used as a dehydrating agent.

This alcoholic washing was allowed to evaporate under observation. A stage was reached when globules began to separate out of the solution. Under 4D these globules could be seen to contain fine needle-like fatty acid crystals. When the solution containing these was placed on the slide, the crystals were very evident. As the alcohol evaporated they disappeared as though by explosion, very fine clear globules remaining. If evaporation was prevented by placing a cover-slip on the preparation, they retained their form and remained visible for several hours.

¹ J. Lorrain Smith. *Staining of neutral fat and fatty acid by oxazine dyes*. Jour. Path. Bact., vol. 12, 1907.

When a drop of the alcoholic solution was mixed with one of water, the needle-like crystals retained their form and did not disappear. It was possible to bend them into crescents by slight warming over a flame. On staining with Nile blue sulphate the crystals were unaffected. The other constituents took on the blue stain.

Drops of the alcoholic solution, dried slowly on slides, were placed in 1:250,000 neutral red solution at 38° C. for 24 hours. (Method of Parat for demonstration of the vacuome, Lee, '28, page 353.) At the end of 6 hours, small red globules within larger globules were evident; at the end of 24 hours the small globules were no longer visible, the larger globules having become uniformly stained. The small globules seemed to be those derived from the fatty acid crystals.

Drops of the alcoholic washing were mixed with an equal quantity of water, dried with heat and fixed in Mann-Kopsch. When extracted 45 minutes in turpentine, black droplets, derived from the fatty acid crystals, in a grayish granular matrix could be seen. Some of these droplets had a clear halo, formed because the surface of the droplet had been dissolved; some had lost their centers by solution and some had evidently been completely dissolved. There were some granules and some crescentic rims of vesicles that were more resistant to extraction than others; these were very black.

Commercial cholesterol blackens in osmic acid. Cholesterol crystals were seen in the evaporated alcoholic washing, and the dried alcoholic washing dissolved in chloroform gave a weak positive reaction for cholesterol by the Salkowski method. It is therefore possible that some of the blackening may be due to cholesterol or to cholesterol esters. We have no evidence on which to base a distinction between these and the fatty acids.

Droplets of the alcoholic washing that were dried and placed in neutral red showed, after 10 hours, a foam-like or honey-comb structure, with plates (?) or crystals (?), stained red, between the vesicles. Similarly, if droplets were allowed to evaporate slightly on the slide and then a drop of Nile blue sulphate added, they showed blue networks, structure identical with that observed in the neutral red preparations.

It seems probable that the greater part of the persistent blackening and of the staining reaction is due to the presence of the derivatives of the fatty acid crystals, and that a lesser part is due to the presence of cholesterol. This conclusion is based on the fact that the blackened or stained bodies have the position and form of those which may be seen to arise from the fatty acid crystals.

(3) *Cholesterol control*: Merck's cholesterol, dissolved in ether and emulsified in water and chloroform, was sucked into prepared pith, fixed, embedded and sectioned. The results of the examination of the sections are presented in Table 5.

2. Extracted in turpentine, unstained:

Extracted 24 hours. Crystalline structure more evident than in unextracted slide, indicating probably that a small amount of cholesterol has been removed by the turpentine. Cholesterol may be attacked by turpentine but it is not completely removed as is fat. Some blackened material in the form of fine rods and granules is collected around (at the edge and on top of) the crystals.

No effect (see 1)

3. Slides extracted in turpentine, stained:

Extracted 24 hours. No fuchsin-stained material.

No effect.

4. Slides not extracted, stained:

No fuchsin-stained material.

Fine curved threads and granules stained more deeply than the spheres, the latter probably to be interpreted as the solvent or emulsifying agent. (The evidence for this is obtained from control material in which ether, chloroform and water only were sucked into pith.)

(4) *Cephalin fraction* (four times precipitated from ethereal extract with warm alcohol): Cephalin readily forms a colloidal solution in water. An examination of sections made from prepared pith, which had been impregnated with an aqueous solution of cephalin and fixed, made it evident that another method of study must be devised. The Mann-Kopsch material showed somewhat flocculent masses of black. The Champy-Kull material was undifferentiated except for a few dense, but unblackened areas. There was no evidence of granules in either lot of material.

Drops of an aqueous solution of cephalin were injected into small globules of celloidin that had been allowed to harden on their surface in chloroform. These globules were then fixed, embedded, sectioned and mounted in the usual way. Smears of a solution of cephalin on slides were also fixed and studied, and drops of a thick solution of cephalin were floated on the surface of Champy-Kull fluid, and fixed as films. The results are presented in Table 6.

TABLE 6

*Mann-Kopsch**Champy-Kull*

1. Unstained:

Sections in celloidin: Spherical globules down to the limits of visibility, deeply blackened by osmic acid. Some linear dark streaks containing black droplets at intervals.
Smear: Grayish masses; no globules.

Sections in celloidin: Homogeneous groundwork with brownish granular inclusions.
Film: brownish granular mass.

2. Stained:

Sections in celloidin: Globules (see 1) were stained pink.
Smear: Homogeneous pink masses.

Sections in celloidin: Granules (see 1) stained pink.
Film: Granules and floccular mass stained pink; many stained thread-like filaments.

In preparing the material, prolonged treatment with absolute alcohol must be avoided because of its solvent action on the celloidin. Sections and films were cleared in bergamot oil, washed in xylol and mounted in balsam.

Our study showed that because of the smallness in size of the particles in the disperse phase, no staining reaction of these could be demonstrated. In concentrated or mass suspension, cephalin is blackened by osmic acid and may be stained with fuchsin. It was evident that Mann-Kopsch fixation gave a more exact fixation image than did the method of Champy-Kull.

Experiments with vital dyes: Hanging drops of a solution of cephalin and Janus green were prepared. With a needle the cephalin solution was dragged to the drop of Janus green so as to form a bridge between the two drops.

(1) Janus green 1:10,000: An intensely stained blue membrane was formed at the boundary between the two solutions, a membrane that was not permeable to either substance. No diffusion occurred.

(2) Janus green 1:20,000: Membrane formed at boundary of solutions of cephalin and dye. Stain less intense than in 1:10,000.

(3) Janus green 1:40,000: Bluish streaks not resolvable into granules were formed.

(4) Janus green 1:80,000: No effect evident.

When solutions of cephalin and Janus green 1:10,000 were mounted as a mixed drop under a cover-slip, the same type of precipitation was observed, the membrane having the appearance of deeply stained blue filaments made up of granules. Mounted in this way, the center of the solution of cephalin gradually took on a pinkish color. There never was a return to the condition of the leucobase of the dye.

When hanging drops of neutral red 1:80,000 and cephalin were connected, all of the neutral red was thrown down. No membrane nor streaks were evident.

(5) *Lecithin fraction* (twice precipitated from acetone, dried over night in vacuum desiccator over P_2O_5). Aqueous emulsion sucked into prepared pith, fixed, embedded and sectioned. The results are presented in Table 7.

TABLE 7

<i>Mann-Kopsch</i>	<i>Champy-Kull</i>
1. Slides not extracted, not stained:	
Very black droplets and masses.	Grayish-black foam-like structure. Walls of the droplets dark as though the emulsion had been water in lecithin.
2. Slides extracted in turpentine, not stained:	
Yellowish crystalline masses.	Extracted 30 minutes. Beautiful grayish emulsion.
3. Slides extracted in turpentine, stained:	
Extracted 20 minutes: Very black droplets and masses; some thin masses show foam-like structure of the emulsion.	Extracted 30 minutes: Globules, droplets and granules deeply stained with fuchsin.
Extracted 6 hours: Aggregates of droplets in black masses. Evident that fuchsin has been retained by the droplets.	Extracted 1 hour: Very dark red masses of droplets.
Extracted 24 hours: Blackened aggregates of droplets, some with clear center and black rim. The rims are stained red over black.	
4. Slides not extracted, stained:	
No effect of stain evident.	Foam-like structure; pink matrix.

With proper extraction the drops of the emulsion show a pink matrix containing clear spheres and some red, some red over black, granules. A thin pink rim surrounds the foam-like drops.

An emulsion of lecithin in water was forced with a pipette into drops of celloidin which had been superficially hardened in chloroform. These drops were fixed in Mann-Kopsch and in Champy-Kull, embedded and sectioned. The results of the observations on this material are shown in Table 8.

TABLE 8

<i>Mann-Kopsch</i>	<i>Champy-Kull</i>
1. Slides not extracted, not stained:	
Very black small granules, somewhat aggregated.	Finely granular, grayish-black mass; some thick-walled vesicles.
2. Slides extracted in turpentine, not stained:	
Extracted 15 minutes. Granules gray instead of black; same type of aggregation as in 1.	Extracted 5 minutes. Grayish-black color has disappeared. Bright refractive granules and vesicles instead.
3. Slides extracted in turpentine, stained:	
Extracted 1 hour. Aggregates of pink granules.	Extracted 15 minutes. Well-stained pink granules.
4. Slides not extracted, not stained:	
No evidence of stain.	Pink granules.

The results show that when lecithin is blackened by osmic acid, the blackening may be removed by extraction in turpentine, leaving a residue that will stain with acid fuchsin.

(6) *Commercial lecithin*: As a check on the extracted lecithin, purified commercial lecithin was emulsified with ether, chloroform and water, sucked into pith, fixed, embedded and sectioned. The results of the examination of this material are given in Table 9.

TABLE 9

*Mann-Kopsch**Champy-Kull*

1. Slides not extracted, not stained:

Small evenly blackened spheres and masses.

Small yellowish crystalline masses.

2. Slides extracted in turpentine, not stained:

Extracted 10 minutes. Small evenly blackened spheres. Masses have become lighter in color.

Extracted 10 minutes. The same appearance as 1.

Extracted 30 minutes. Small evenly blackened spheres. Masses have assumed the appearance of groups of yellow platelets.

3. Slides not extracted, stained:

Same as 1, stained red over black.

Small spherules stained uniformly with fuchsin; larger ones with rim more deeply stained than central region.

4 Slides extracted in turpentine, stained:

Extracted 75 minutes. Small spheres stained red over black. Masses of platelets stained pink over yellow.

Extracted 15 minutes. Rods and granules stained slightly deeper than in the unextracted slides.

The study of the slides made it evident that two phases of fixed lecithin were represented; one, a solution of lecithin in chloroform or ether, the other an emulsion of lecithin in water, the lecithin having come out of solution due to the evaporation of the solvents. The dissolved lecithin appeared in the fixed preparations as small spherules, the undissolved as platelets. Lecithin stains red with acid fuchsin after Champy-Kull fixation, and similarly after Mann-Kopsch, although in the latter the red of the fuchsin is superposed on the osmic blackening.

The results of this investigation demonstrate specificity of staining reaction to the reagents used. In the fixed and stained preparations of extracted substances, as well as in those preparations stained "intravital," it has been possible to observe structures that are similar in appearance to the formed components or inclusions of the egg, and to define within limits the chemical nature of those structures. Similarity of fixation images is not a proof of identity of structures, and the authors wish to draw no conclusions to this effect. The most that can be said is that fixed inclusions may be very accurate pictures of different stages of chemical processes. However, it would be equally difficult to claim that formed components of the cytoplasm are more than pictures of stages in anabolic and catabolic reactions.

A more complete report of the material here outlined, together with a description of the results obtained from the direct study of the tissues will be made shortly.

R. H. Bowen. *The methods for the demonstration of the Golgi apparatus III. Methods of osmic impregnation.* Anat. Rec., vol. 39, 1928.

Belles Lee. *The microtome's vade mecum* 9th Edition, 1928.

J. Lorrain Smith. Staining of neutral fat and fatty acid by oxazine dyes. Jour. Path. Bact., vol. 12, 1907.

D. H. Tennent. Carnegie Institution Year Book, No. 26, 1927.

BOTANY

Babcock, E. B., University of California Agricultural Experiment Station, Berkeley, California. *Investigations in the genus Crepis*. (For previous reports see Year Books Nos. 25, 26.)

The principal objective of these investigations is a clearer understanding of the evolutionary processes at work in this group of about 200 related species. During the past year the work has been conducted mostly along four main lines, *viz.*: taxonomic studies; work on the chromosomes of species in relation to their classification; genetic and cytologic study of interspecific hybrids; and the investigation of chromosomal variations.

Taxonomy—The work of revising the classification of the entire genus has proved a more difficult and time-consuming undertaking than was anticipated, but it is believed to be an undertaking which should be completed as soon as possible. The most difficult problems are concerned with the delimitation of the genus and the phylogeny of the subgroups within the genus. In this difficult work the evidence from comparative morphology has been supplemented, in so far as possible, with evidence from cytology, genetics and geographic distribution. It now appears that *Crepis* originated, probably at more than one place and from several ancestral stocks, somewhere in Asia, and that distribution has been westward into Europe, southwestward into Africa, and northeastward into North America.

Chromosome Morphology—The study of chromosome morphology is proving very useful, not only in helping to solve difficult problems of classification, but also in research on the genetics of species and their hybrids. In this field *Crepis* has even greater advantages over most other plant material than was at first realized. Not only is the number of chromosomes in many species very low, but, equally important, each pair of chromosomes can at certain stages be distinguished from all the other pairs. The finer details of chromosome morphology have been worked out in 25 Old World species, or nearly half of such species now under cultivation.

Interspecific Hybrids—Over 60 hybrids between different species have been grown. Many of these hybrids possessed some degree of fertility, and from some of the earliest ones progeny of the ninth generation are now growing. The morphology of these hybrids, their degree of fertility and the nature of their progeny are of value in connection with problems of classification. They also throw light on the evolutionary processes at work in *Crepis*. Among the progeny of certain of these hybrids it has been possible to obtain new constant races having all the qualities of new species, except that they are not found growing wild. The most fully worked out case of this sort is *Crepis artificialis* of Collins which was derived from a hybrid between *C. biennis* ($n=20$) and *C. setosa* ($n=4$). It has 12 pairs of chromosomes, is highly fertile, breeds true and combines characteristics from both parents. Such demonstrations that new species can originate by interspecific hybridization indicate one probable method of evolution in *Crepis*. They are supported by the extensive evidence already secured that natural hybrids actually occur among several different species and result in fertile intermediate hybrid forms.

Chromosomal Variations—Most convincing evidence as to the basic rôle of the chromosomes in heredity is found in plants having abnormal sets of chromosomes. In *Crepis* three classes of such abnormalities have thus far been studied:

(1) Interspecific combinations. Besides the many F_1 hybrids between species, several remarkable F_2 combinations have been secured by crossing F_1 hybrids with a third species, thus giving hybrids possessing chromosomes from all three species. Occasionally very remarkable combinations are obtained by this method. For example, such a hybrid was found by Navashin to possess one full set of chromosomes of *C. alpina* ($n=5$), one from *C. tectorum* ($n=4$), and one from *C. dioscoridis* ($n=4$). This plant was a blend of all three species and was very vigorous but completely sterile.

(2) Polyploids. In several species of *Crepis*, plants with one or more complete extra haploid groups of chromosomes have been secured. The characteristics of triploids and tetraploids are in general agreement with those of similar forms in other genera of plants. Most of our polyploids have been found among interspecific hybrids and possess two or more n -groups from one species plus one n -group from another species. The exaggeration and suppression of certain distinctive specific characteristics in such plants are most convincing as to the importance of the chromosomes in ontogeny.

(3) Haploids. A remarkable by-product of the work on the interspecific hybrids was the discovery of the first haploid *Crepis* plants. It is especially interesting that these should have been derived from *C. capillaris* in which the haploid number is 3. These haploids, therefore, have only 3 chromosomes per cell, the smallest number yet known in angiosperms. Their origin is explained as due to development of an unfertilized egg following application of pollen from another species. It has been found also that these haploids are capable of restoring the normal diploid number, probably by a delayed somatic cell division, giving rise occasionally to a diploid branch on a haploid plant. No fertile seeds have been obtained from these haploid plants except from one diploid branch. This seed should, of course, yield progeny which is completely homozygous and hence especially valuable in future genetic work.

The following persons have assisted in the work: Dr. J. L. Collins, assistant professor of genetics; Dr. J. Clausen, assistant geneticist in the Royal Veterinary and Agricultural College of Copenhagen; Mr. M. Navashin, director of research on experimental evolution in the Timiriasev Federal Institute of Scientific Research of Moscow; Miss E. L. Hollingshead, assistant in genetics; Miss Priscilla Avery, assistant in genetics; Mr. Charles F. Poole, assistant in genetics; Mr. C. W. Haney, technical assistant.

Improved facilities for the culture of *Crepis* species and hybrids have become available through the courtesy of the administration of Stanford University in permitting the establishment of an auxiliary garden which is ideally situated. All the perennial species obtainable will be maintained there as well as extensive experimental cultures.

CHEMISTRY

Noyes, Arthur A., California Institute of Technology, Pasadena, California. *Researches upon* (1) *free energies and reduction-potentials*; (2) *the structure of crystalline substances determined by X-rays*; (3) *rates of gaseous chemical reactions*; (4) *the mechanism of carrier catalyses*; (5) *chemical reactions produced by molecules activated by radiation*; (6) *chemical reactions produced by molecules activated by electron impact*; (7) *reflection of electrons from crystals*; (8) *far infra-red spectra*; (9) *X-ray absorption in relation to the valence and other properties of atoms*; (10) *atomic and molecular structure—theoretical*; (11) *general thermodynamics*. (For previous reports see Year Books Nos. 2-26.)

Continuation of appropriation of funds by the Carnegie Corporation of New York to the Carnegie Institution of Washington for the support of fundamental studies in chemistry at the California Institute of Technology has enabled the following investigations to be carried out:

1. FREE ENERGIES AND REDUCTION POTENTIALS

The equilibrium of the reaction $\text{Os(s)} + \text{OsO}_4\text{(g)} = 2\text{OsO}_2\text{(s)}$ between 300° and 500° is being studied by Mr. L. R. Brantley, in cooperation with Dr. D. M. Yost. The equilibrium-pressure of the osmium tetroxide is measured by the use of a so-called click-gage.

Measurements of the distribution-ratio of osmium tetroxide between carbon tetrachloride and water, and between carbon tetrachloride and sodium hydroxide solutions, were made by Dr. Don M. Yost and Mr. Robert J. White. From the results the ionization-constant of the first hydrogen of perperosmic acid (H_2OsO_5) was calculated to be 8×10^{-18} . This small value explains why osmium tetroxide has sometimes been considered not to be the anhydride of an acid.

Mr. H. B. Wellman has investigated the equilibrium between chlorine and the different valence states of palladium in hydrochloric acid solution. It has been found that the equilibrium-ratio of Pd^{II} to Pd^{IV} is not proportional to the Cl_2 pressure indicating that $\text{PdCl}_5 =$ as well as $\text{PdCl}_4 =$ and $\text{PdCl}_6 =$ may be present. The investigation is being continued.

An investigation of the valence states of ruthenium in its chlorine compounds in solution was carried out by Dr. W. R. Crowell and Dr. Don M. Yost. It was found that chlorides which had previously been thought to contain ruthenium in the trivalent state really contain it in the quadrivalent form; and that certain complex ruthenium salts which were thought to be isomers are salts of different valences of ruthenium. It was also established that the blue halide compounds of ruthenium contain the element in the bivalent state.

A study of the reduction potential between trivalent and quadrivalent iridium by the electromotive-force method has been begun by Dr. H. H. Steinour, and is being continued by a graduate student.

2. STRUCTURE OF CRYSTALLINE SUBSTANCES DETERMINED BY X-RAYS

A reinvestigation of the structure of K_2PtCl_6 has been made by Mr. F. J. Ewing and Dr. Linus Pauling. The parameter value u has been determined by them to be 0.240 ± 0.005 . This is considerably larger than the doubtful value 0.16 reported previously by Scherrer and Stoll, but is in good agreement with the value 0.22–0.24 found for $(NH_4)_2PtCl_6$ by Wyckoff.

A new method of predicting the atomic arrangement of complex ionic crystals, based upon the assumption of a coordination structure, has been proposed by Dr. Pauling. This method has been successfully applied by Dr. Pauling and Mr. J. H. Sturdivant to determining the structures of the orthorhombic crystals of brookite (TiO_2) and of topaz ($Al_2SiO_4F_2$).

3. RATES OF GASEOUS CHEMICAL REACTIONS

Experimental and theoretical work on reaction velocities has been continued along the lines described in previous Year Books.

In association with Professor R. C. Tolman, Dr. William Ure has completed and will soon publish his study of the possible effect of excess radiation on the thermal rate of racemization of pinene. The results show that out to a wave-length of 3μ , radiation plays no appreciable part in the thermal reaction. The result is of interest, since the methods of calculation used by Lewis and Mayer working on the same problem do not appear to be justified.

Dr. M. E. Nordberg has continued his work on the decomposition of ozone in the presence of nitrogen pentoxide. He has obtained the rate as a function of the concentration of ozone, nitrogen pentoxide, and oxygen, and of the temperature. The work will soon be published. Dr. Nordberg is now preparing for the measurement of the rate of decomposition of nitrogen pentoxide at very low pressures in a very large vessel.

Dr. O. K. Rice and Dr. L. S. Kassel, National Research Fellows in Chemistry, have spent the past year at the Institute, also working on problems of reaction-velocity, and each has published from this laboratory five papers relating directly or indirectly to this topic.

4. MECHANISM OF CARRIER CATALYSES

The previously reported work of Dr. W. R. Crowell on the reduction of perchloric acid by hydrobromic acid under the catalytic influence of ruthenium salts has been completed. It has been found that trivalent ruthenium is a much more active catalyst than the quadrivalent form; and that the diminution of the catalytic activity with time is due to the slow oxidation of the trivalent to the quadrivalent state by the bromine formed in the reaction. Dr. Crowell has continued the investigation of the same reaction when catalyzed by osmium compounds. In connection with this research he has developed, in cooperation with Mr. H. D. Kirschman, electro-metric methods of determining both octavalent and quadrivalent osmium.

5. CHEMICAL REACTIONS PRODUCED BY MOLECULES ACTIVATED BY RADIATION

The quantum yields in the photochemical decomposition of nitrogen dioxide have been measured by Dr. R. G. Dickinson and Dr. W. P. Baxter. Experimental confirmation has been obtained of Norrish's view that gaseous

NO_2 is decomposed by light into NO and O_2 . By employing a technique permitting experimentation at sufficiently low partial pressures of NO and O_2 , the trimolecular recombination of these gases could be made slow enough to neglect. The quantum yields, expressed as molecules of oxygen produced per quantum of radiation absorbed, have been measured for three approximately monochromatic radiations, and the following mean values obtained: 0.0046 with λ 4350 Å; 0.36 with λ 4050 Å; and 0.77 with λ 3660 Å.

The same investigators have studied the photochemical decomposition of nitrogen pentoxide sensitized by nitrogen dioxide. This work was undertaken in the hope of deciding between two alternative mechanisms which had been proposed: (1) decomposition of N_2O_5 resulting from collisions between N_2O_5 and activated NO_2 ; (2) decomposition of NO_2 into NO and O_2 , followed by a dark reaction of NO with N_2O_5 . The observed rates of decomposition are easily accounted for by the second mechanism, but not by the first.

Dr. A. O. Beckman, in association with Dr. Dickinson, has set up apparatus for the measurement of quantum efficiencies in the ultra-violet. This apparatus includes a quartz monochromator and a sensitive vacuum thermocouple. Study of the photochemical decomposition of gaseous hydrogen azide (HN_3) has been continued. It has been established that the products of this decomposition are hydrogen, nitrogen and ammonia (ammonium azide), and that these products are formed by concurrent reactions. The quantum yield has been measured, and found to be about 2.7 molecules of HN_3 decomposed per quantum absorbed. Experimental evidence has been obtained indicating that this yield is constant, at least throughout a range of pressure from 0.1 to 120 mm. of mercury.

6. CHEMICAL REACTIONS PRODUCED BY MOLECULES ACTIVATED BY ELECTRON IMPACT

The study of reactions of gases activated by the impact of slow electrons has been continued by Dr. R. H. Dalton. An active form of oxygen capable of reacting with carbon at room temperature with formation of carbon dioxide was found to be produced when oxygen gas is subjected to bombardment by electrons which have been subjected to a potential of about 9 volts, but this critical potential has not been accurately determined.

It was found that nitrogen activated by a high-potential electrodeless discharge reacted with copper forming a non-volatile compound; but attempts to produce the reaction by electron bombardment at voltages below the arcing potential failed.

7. REFLECTION OF ELECTRONS FROM CRYSTALS

Work has been started by Dr. R. H. Dalton on the reflection of a beam of electrons from a graphite crystal by a photographic method suggested by Professor L. C. Pauling. The reflected electrons that retain 90 to 100 per cent of their initial velocity are recorded. The work is still in a preliminary stage, but it is hoped that it may yield evidence in regard to the theories of wave mechanics and that it may furnish a means of studying the structure of surface layers.

8. FAR INFRA-RED SPECTRA

Dr. R. M. Badger, with the assistance of Mr. C. H. Cartwright, has investigated the rotational absorption spectrum of ammonia gas in the far infra-red between 55μ and 130μ . An unexpectedly simple spectrum was observed. Six lines were discovered that were approximately equally spaced in frequency; and five of these were accurately measured. A study of the absolute intensities of absorption was also made.

9 X-RAY ABSORPTION IN RELATION TO VALENCE AND OTHER ATOMIC PROPERTIES OF ATOMS

The work on X-ray absorption spectra has been continued. Some compounds of titanium have been investigated. Experiments on a series of iodides and chlorides are also being carried out to test the theory of Aoyama, Kimura and Nishina that the shift of the absorption-edge in a series of salts is related to the lattice energy of the crystals. An investigation of the salts of the polythionic acids is also being made, with the view of increasing our knowledge of their molecular structure.

10. ATOMIC AND MOLECULAR STRUCTURE: THEORETICAL

Dr. Linus Pauling has treated the problem of the structure of the hydrogen molecule-ion, H_2^+ , with the aid of the perturbation theory of the quantum mechanics, and has published this work in a review covering the applications of the quantum mechanics to the structure of the hydrogen molecule-ion and hydrogen molecule and to related problems.

With the use of his expression for the repulsive potential of two ions, he has calculated the changes in interionic distance to be expected to accompany the transition of the rubidium halides from the sodium chloride to the cesium chloride structure. These agree well with the change in volume accompanying the transition observed by P. W. Bridgman, and support the assignment of the cesium chloride structure to the high-pressure forms.

A set of principles governing the formation of ionic crystals and complexes has been developed with the aid of considerations involving the crystal energy or electrostatic energy of the ion complex. These principles are adhered to by all reported structures of complex ionic crystals, except that of cyanite (Al_2SiO_5). The exceptional structure attributed by Taylor and West to this crystal is for this reason probably incorrect. The principles further throw light on the interesting and important problem of the structure of the complex silicates.

These principles have also been applied to the formulation of a coordinated structure for the heteropolyacids, such as 12-tungstosilicic acid, $H_4SiO_4 \cdot 12WO_3 \cdot xH_2O$. The proposed structure explains the pronounced difference in properties of these acids and the ordinary acids of tungsten and molybdenum, leads to a number of replaceable hydrogen atoms in agreement with experiment, and accounts for the high water-content of crystals of the acids and their salts, for their tendency to have cubic or pseudocubic symmetry, and for the formation of condensed acids such as $H_3PO_4 \cdot 9WO_3 \cdot xH_2O$.

11. GENERAL THERMODYNAMICS

Professor R. C. Tolman has been engaged during the year in theoretical studies on the extension of thermodynamics to general relativity, and has

published an article bearing this title as well as other papers on the energy and entropy of Einstein's closed universe, and on the equilibrium between radiation and matter in Einstein's closed universe.

PUBLICATIONS

During the past year thirty-two articles have been published, mostly in the Journal of the American Chemical Society, describing the researches outlined above or in last year's Year Book.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. *Continuation of exact investigation of atomic weights and other physico-chemical properties of elements and of simple compounds.* (For previous reports see Year Books Nos. 2-26.)

Owing to the death of Dr. Theodore W. Richards, this report has been prepared and submitted by Dr. Lawrence P. Hall.

The following investigations have been in progress during the academic year, some of them continuations of work begun in previous years.

ATOMIC WEIGHT OF CESIUM

The determination of the atomic weight of cesium by analysis of the chloride has been completed by Marcel Françon. The present accepted value of 132.81 is confirmed and the deviation from an integral value is thus shown to be unusually large, provided that Aston's conclusion is correct that cesium is a simple element.

ACTION OF CHLORIDE SOLUTIONS ON MERCUROUS CHLORIDE

Mr. Françon has also continued the study of the action of concentrated chloride solutions on mercurous chloride in order to show the behavior of strong electrolytes.

SPECIFIC HEATS OF AQUEOUS SOLUTIONS

A study of specific heats of solutions of hydrochloric acid at various concentrations was made by Dr. Lawrence P. Hall with the aid of the differential twin-calorimeter system used in previous work. These data, together with the heats of dilution of solutions of hydrochloric acid determined by Dr. Beveridge J. Mair, permit an accurate calculation of the specific heats of these solutions over a very wide range of concentrations.

For the determination of the specific heats of solutions over a wide range of temperatures, Dr. Frank T. Gucker jr. has further developed an improved twin calorimeter. With this apparatus Dr. Malcolm Dole has measured the specific heats of several concentrated solutions of barium chloride and calcium chloride.

HEATS OF DILUTION

Dr. Mair continued the study of the heats of dilution of weak and strong acids. Dr. Gucker extended his earlier work on the dilution of sodium hydroxide solutions to cases of still smaller concentrations. On the other hand Dr. Hall studied the heat of dilution of the more concentrated solutions of sodium hydroxide. Dr. Dole measured the heats of dilution of

barium and calcium chloride solutions. He had previously measured the electro-chemical properties of barium chloride solutions under the direction of Professor Grinnell Jones.

COMPRESSIBILITY OF ELEMENTS

The cubic compressibilities of several elements which had not previously been available for measurement at this laboratory were investigated by Dr. Mair and Dr. Hall. Values for the compressibility of barium and beryllium were obtained, which agree with those found by an independent method. Work was also done with sodium, strontium and vanadium. Several improvements were made in technique and in the construction of the apparatus for measurement of compressibility. As a by-product of this work, a new type of specific gravity bottle for solids was developed to yield a high degree of accuracy with ease of manipulation.

A list of papers which have been published during the past year will be found in the bibliography. Accounts of the other researches which have been in progress during the past few years will be published during the next few months.

Sherman, H. C., Columbia University, New York, N. Y. *Chemical investigation of the amylases and related enzymes.* (For previous reports see Year Books Nos. 11-26.)

One phase of this investigation, referred to in previous reports, having to do with the establishment of the optimal hydrogen ion activities for the enzymic hydrolysis of starch by pancreatic and malt amylases under varied conditions of time and temperature, has been published during the past year in the Journal of the American Chemical Society. In the same Journal, we have also published the results of a quantitative study (not subsidized by the Institution but coordinated with and helpful to its work) of the influence of the so-called buffer salts, sodium acetate, sodium borate, sodium citrate and sodium phosphate, upon the activity of pancreatic amylase.

The work thus completed afforded the needed background for extended and rigorous experiments upon the relation of typical neutral salts to the enzymic activities of these amylases. The studies made with pancreatic amylase in this connection, to which brief preliminary reference was made in the report of last year, have now been completed and prepared for publication and will appear in the Journal of the American Chemical Society. This part of the work, as fully developed, involved three phases:

(1) The interrelation of hydrogen ion activity and concentration of salt in the activation of the amylase, in which a long series of experiments showed that the optimal hydrogen ion activity for the catalytic action of this enzyme is dependent upon the kind and the concentration of the salt present.

(2) The influence of the concentration of neutral salt upon the activation of the enzyme, the optimal concentrations (in terms of molarity) being found to be different for different neutral salts. (3) A quantitative comparison of the influence of different neutral salts upon the enzymic activity when each salt is used in such concentration, and in the presence of such hydrogen ion activity, as had been found most favorable to its activation

of the enzyme, the salts which are less favorable to the activity of pancreatic amylase being required in higher concentration and (in turn) exerting their most favorable influence in solutions of higher hydrogen ion activity than do those salts which are more efficient activators. Thus tested, the influence exerted by different neutral salts appears to be very specific, and the specific effect to be much more largely due to the anion than to the cation. Beginning with the most favorable, the salts studied showed the following order in their influence upon the hydrolysis of starch by pancreatic amylase: sodium and potassium chlorides, lithium chloride, sodium bromide, sodium nitrate, sodium chlorate and sodium sulfocyanate, sodium fluoride. Sodium sulfate and sodium phosphate were found to be without influence upon the activity of this enzyme.

Much of our attention has also been given to the problem of possible improvements in the method of purification of pancreatic amylase. As yet we find no convincing evidence, either in our own work or that of others, that the newer methods will afford purer and more active products than were obtained in this laboratory by the method which we developed from that of Osborne and described some years ago; but the more recently proposed adsorption methods have attracted such favorable consideration, and the importance of the problem of purification to our studies of the chemical nature of these enzymes is so great, that it has seemed wise to undertake a thorough reinvestigation of the subject, with special reference to the precise establishment of the optimal conditions for each step in the purification process and the possible advantage of combining the adsorption method with that previously employed in this laboratory. This involves a large amount of the most painstaking experimentation, and this phase of the investigation is now actively in progress and does not yet permit of more than preliminary report. Each of the several steps involved in the purification process must be carried out repeatedly under systematically varied conditions, and all products carefully examined for enzymic activity by delicate and time-consuming quantitative methods in order to ascertain how best to insure the greatest increase of purity with the least destruction of the enzyme, as well as to furnish further information concerning the physico-chemical properties of the enzyme as reflected in its behavior under the different combinations of conditions imposed. Thus far, it has been found possible to introduce a phosphate buffer mixture into the enzyme solution at a much earlier stage in the purification than in previous work in which adsorption processes have been employed. This permits a higher degree of accuracy in the study of the relation of hydrogen ion activity to the optimal conditions for each step in the purification of the enzyme, and, moreover, enables us to define the conditions for each step in such terms as to place it upon a more precisely reproducible basis.

A study of the influence of hydrogen ion activity on the clarification of, and precipitation of inert proteins from, the glycerol extract of pancreatin by means of their differing solubilities in water and glycerol indicated a marked advantage of adjusting these solutions to hydrogen ion activities of about pH 5.6 to 6.0. Solutions thus adjusted were clearer and the activity per milligram of nitrogen was frequently higher than in the more alkaline

solutions. These conditions have therefore been maintained at this step of the process in all the following experiments.

A determination of the most favorable conditions for adsorption of pancreatic amylase by alumina necessitates a study of the many factors involved, such as, concentration of alcohol, enzyme, alumina and the hydrogen ion activity. While this phase of the work is still incomplete, sufficient data have already been obtained to show that the reaction of the solution during adsorption has a very decided influence on the amount of adsorption. Maintaining a constant concentration of enzyme and alumina, the influence of the reaction of the solutions during adsorption has been investigated in the presence of 0, 10, 25, 40, 55 and 70 per cent alcohol, and the adsorption of the enzyme has usually been found to be high in solutions of pH 6.0 to 7.0. The conditions are being studied further.

We plan to continue this work during the coming year, and thus to develop a definitive method for the preparation of the best possible purified form of the enzyme for use in our final studies of its chemical nature and mode of action.

The efficient collaboration of those who have shared in this work, whether as research assistants or volunteers, is gratefully acknowledged.

GEOLOGY

Chamberlin, T. C., University of Chicago. *Certain fundamental problems of geology.* (For previous reports see Year Books Nos. 2-26.)

The larger part of the past year has been taken up with the completion and carrying through the press of a book containing a succinct but comprehensive summation of Mr. Chamberlin's studies relative to the genesis of the Earth and kindred bodies. The exposition has been extended strictly along the lines of the planetesimal theory, not only to the peculiarities of the planets, planetoids and satellites which constitute the planetary family, but, in a modified form, to the chondrulites, comets and meteorites which constitute the cometary family. The latter have been found to have a significant kinship to the planetary family, though it is held to have had a quite distinctive origin. This relationship throws much light upon the genesis of all the sun's derivatives. The book has therefore been entitled *The Two Solar Families, The Sun's Children* (University of Chicago Press). As implied by the latter clause of the title, not only the planets, planetoids and satellites, but also the chondrulites, comets and meteorites are all held to be derivatives of the sun, and therefore constitute its children, *not* its captured slaves.

A very brief synopsis of the leading features of this two-fold genesis is given in the last Year Book of the Carnegie Institution, but a fuller statement has been deemed necessary to show even the main features of the evolution and the relationship of the two branches of the solar family.

Though the planetary family and the cometary family are held to have had a common parentage from the sun, it is also held that both were bipolar, and that the second parentage in the two cases was quite different in dynamic qualities, and that from this difference arose the wide differences and even contrasts between the two families. It is therefore quite as important that these differences be realized as that the kinship should be.

When, in the course of following, as strictly as possible, the application of the principles of the planetesimal hypothesis to the evolution of the gaseous bolts shot forth from the sun under the stimulus of the postulated passing star, it was found that there would arise a residual swarm of heavy, slow-going accretions in revolution about their common center of gravity, not unlike a swarm of gnats as seen in the glint of the setting sun, it was almost an inevitable further step to the recognition of the structure of a comet's head as an analogous swarm of chondrulites in similar dynamic organization. Thus the study passed from residual planetary swarms, derived from planetary bolts (which evolved mainly into planetesimals) to less massive solar projections which evolved into chondrulites. A part of these little seed-like accretions, in the outer domain of the sun's control, is held to have assembled into revolutionary swarms which functioned, for a time, as comets' heads.

The logical deduction from the conditions postulated by the planetesimal hypothesis that the core of the earth and other planets was formed primarily from a swarm of heavy accretions is believed to be, in itself, a contribution to planetary cosmology of a high order of value. That it should lead on

to an unexpected elucidation of the essential features of the cometary family adds to its inherent probability.

Within the planetary family, the concept led on to several felicitous elucidations of what had been puzzling features. By definite, logical steps it led to a slow solid growth of the earth by which one hemisphere became denser than the other. Later it led to the development of the continents in offset pairs, giving the planet a roughly ribbed meridional but oblique arrangement in sharp distinction to the theoretical east-west belting which might be expected to arise from rotation—which in fact, did arise without masking the dominant meridional ribbing. The cosmological studies have thus led by firm steps to a very definite concept of the growth of the earth in harmony with the recent and growing evidence that the earth is essentially a solid body.

On the study of this growth much progress has already been made. This indicates the chief line of future study. Already it foreshadows definite light on the special subject from which the cosmological departure started. The problem of the earth's periods of glaciation has been given some attention during the year, as intervals in the task of publication have permitted and some notable advances have been made, especially in the line of tilting of the continents during the course of the succession of glacial advances that make up the complex record of a typical stage of glaciation. The origin of the ice invasions was the point of departure of these cosmologic studies, and it is the purpose to bring the study about to the point of its origin.

Udden, J. A., University of Texas, Austin, Texas. *Study of the laminated structure of certain drill cores obtained from Permian rocks of Texas.*

During the year I have finished and submitted a report on measurements on laminations in the anhydrite core from the Gresham and McAlpine boring in Culberson County, Texas. This report was accompanied by a paper by Dr. Dodd, giving results of his study of about 1,450 measurements of layers in these cores.

Dr. Dodd states that in the measurements he has examined, he has found some evidence of cycles of the lengths of 10, 11, 19 and 33 layers. In some banded cores, in which groups of dark and bituminous layers alternated with light layers, he found some evidence for cycles of 7, 7.5 and 10.5 layers.

No positive conclusion as to whether or not these laminations reveal the existence of a sunspot period in Permian time can thus be announced. The failure to find such a period may be due to the fact that it did not exist, or that it is concealed by many unknown factors affecting the sedimentation of the anhydrite, or to the impossibility of judging what constitutes a layer in making some of the measurements. It may also be due to the lack of sufficient refinement and accuracy in making the measurements.

But it must be admitted that the variation in the length of the cycles revealed is of the order of variations noted in the length of the sunspot cycles during the time this cycle has been observed and recorded. Such being the case further study of the laminations of this anhydrite seem to be warranted. At any rate my own study and that of Dr. Dodd are only rough attempts at the solution of an involved problem which may in all likelihood some day yield positive results.

HISTORY OF SCIENCE

Sarton, George, Cambridge, Massachusetts. *Associate in the history of science.* (For previous reports see Year Books Nos. 18-26.)

The present (tenth) report covers the period July 1, 1927, to June 30, 1928.

1. *Introduction to the History and Philosophy of Science*—The first volume, From Homer to Omar Khayyam (xii + 840 pages), was published in May 1927. A small edition printed for the Carnegie Institution was at once followed by a larger one distributed by Williams and Wilkins of Baltimore. The second volume dealing with the development of positive knowledge from the twelfth to the fifteenth century is practically complete, as far as the collection and study of materials are concerned. The final manuscript will be ready for the printer in 1929. The preparation of this second volume was delayed by the fact that I was obliged to study Hebrew. Even now a day of each week must be entirely given to the reading of Arabic and Hebrew. This volume will contain, among other things, the first detailed comparison of the Latin and Hebrew transmissions of Græco-Arabic knowledge. The Chinese notes of volume 2 will be specially valuable, because, thanks to the cooperation of Mr. Arthur W. Hummel, Chief of the Oriental Division of the Library of Congress, it has been possible to add references to a great number of editions of Chinese texts, *e.g.* those included in the many Chinese collections or *ts'ung shu*. Another cause of delay was the necessity to make a check list of the notes relative to volume III (sixteenth century) in order to withdraw from among them those which really pertain to the end of the fifteenth century and must be used in writing volume II.

The amount of materials on the history of science reaching me from everywhere is increasing so fast that the time spent in registering and classifying them has become quite considerable. If this increase continues, and there is every reason to believe that it will, the additional work thus created will require the exclusive attention of an assistant. I am anxious that all materials be classified so that they may be easily available not only to myself, but to other students even in my absence.

2. *The Publication of Isis*—During the past year I have edited four numbers of *Isis*, forming the end of volume 9 (pages 221 to 718) and the beginning of volume 10 (pages 1 to 328), a total of 826 pages, 24 plates. They contain 16 papers, 28 shorter communications, 47 reviews, about 2,115 bibliographic notes, and a general index to volumes 7 to 9. The increasing number of valuable papers offered to the editor of *Isis* as well as the scientific needs of an expanding branch of research, make it imperative to enlarge the journal, and this raises very difficult problems.

3. *Lectures*—A series of 34 lectures on the history of science in the eighteenth and nineteenth centuries was delivered at Harvard University and Radcliffe College.

LITERATURE

Bergen, Henry, London, England. *Research Associate in early English literature.* (For previous reports see Year Books Nos. 11-23, 25.)

During the past year Dr. Bergen has been engaged in preparing for the press Part IV of Lydgate's *Troy Book* consisting of a bibliographical introduction, notes on the text, glossary and index. The preceding parts of this edition have been published by the Early English Text Society and the present volume will complete the work.

MATHEMATICS

Lehmer, D. N., University of California, Berkeley, California. *Completion of stencil device for finding factors of larger numbers.* (For previous report see Year Book No. 26.)

The master stencils are completed for all numbers, plus and minus, up to the limit 239, which is as far as it is proposed to carry the work at present. An edition of fifty copies is being cut, and already some twenty numbers are completed.

METEOROLOGY

Bjerknes, V., Oslo, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5-26.)

1. Perhaps the most important progress of later years has been that it has proved possible to bring the problem of the atmospheric disturbances, or at least their primary formation, under the scope of mathematical theory through the formulation of general "equations of atmospheric disturbances." With these equations it is possible to advance analytically on account of their linear form.

As mentioned in earlier reports, Mr. Solberg has taken up the systematic work to find such integrals of these equations which correspond as closely as possible to the conditions under which cyclones are formed. The work has had to start with the easiest cases and to approach the more difficult ones, in which the conditions always are laid closer to the actual ones, as they are observed on the synoptic maps.

The first extensive paper on the results gained by Mr. Solberg is ready for press, *Integrationen der atmosphärischen Störungsleichungen. Erster Teil: Wellenbewegungen in rotierenden homogenen und inkompressiblen Flüssigkeitsschichten* (Geofysiske Publikationer, Oslo, 1928).

In this paper the atmosphere is provisionally considered as consisting of incompressible strata, a supposition which greatly facilitates the progress up to a certain point, the first object being to ascertain how the rotation of the earth effects the disturbances. In the first part of the paper the surface of discontinuity—which is subject to the disturbance—is supposed not to cut the earth, while it may be level or inclined according to the well-known Helmholtz-Margules formula. In this case the integrals may be expressed by exponential and trigonometric functions. The complete and exhaustive discussion of all possible elementary solutions must necessarily be performed as a preparatory work for the subsequent mathematically more difficult investigations.

At the end of the paper the general solution is also given for the case when the surface of discontinuity cuts the earth, *i.e.* conditions under which, according to experience from synoptic maps, actual cyclone formation takes place. It has proved possible to express the general solution for this case by use of cylinder functions. The discussion of the solution, in order to see its full content, is still an extensive task, which must be reserved for the next part of the paper; but it has been prepared as carefully as possible by discussion of all the elementary cases.

2. Parallel with these first attempts of integration of the atmospheric equations of disturbance have gone continued investigations concerning the equations themselves.

As it is known, we have the general hydrodynamic equations in two different forms, the *Eulerian* and the *Lagrangian*. They are developed side by

side in all treatises of hydrodynamics, but in practical application the Eulerian equations have been used almost exclusively. The Lagrangean have been considered too difficult to be handled mathematically.

But after the discovery of the frontal phenomena, and the development of the modern methods of weather analysis (see the report below on the work of Mr. Bergeron), meteorology has always developed more decidedly toward the Lagrangean method of viewing the problem. According to the "Bergen Methods," the physically different *air masses* are followed on the synoptic maps, while the mere mapping out of the *fields* of the different variables, describing the actual states, is no longer found sufficient.

Although I also was under the general prejudice of the hopelessly difficult character of the Lagrangean equations, I was compelled by these considerations to undertake a comparative study of the two systems of equations. This has led to the following unexpected results:

It is only within a certain limited field that the Eulerian system of equations is actually simpler than the Lagrangean one, namely only as long as the exchange of any two masses of the fluid does not involve any change in the field of mass. But in case of non-exchangeable fluid particles—as in atmosphere or sea—the Lagrangean system of equations is simpler than the Eulerian one. The equation generally called the "supplementary" or "fifth" one, which gives the internal physical properties of the particles, has in the Lagrangean system always finite form, while in the Eulerian system it can retain finite form only in the case of exchangeability of the particles. In the general case it must be expressed in the form of a differential equation, which when added to the other differential equations makes the complete Eulerian system more complicated than the Lagrangean. This fifth Eulerian differential equation has, as far as I know, hitherto not been formulated. It will be given in my paper on the subject.

This essentially simpler nature of the Lagrangean system shows itself decidedly when the equations are brought to that linear form which applies to small disturbances. The equations of atmospheric disturbances as derived from the Lagrangean equations are, as I have now been able to state, actually easier to deal with than those which I have previously derived from the Eulerian equations.

This Lagrangean form of the equations will lay a new basis for the whole mathematical theory of atmospheric disturbances. For Mr. Solberg's continued work this will be an advance of importance, especially when he passes from the case of incompressible to that of compressible strata.

3. The work of Mr. Bergeron, referred to in previous annual reports, has advanced so that he is now reading the last proof-sheets of a paper, *Ueber die dreidimensional verknüpfende Wetteranalyse. Erster Teil: Principielle Einführung in das Problem der Luftmassen und Fronten-bildung*.

What is now generally called the "Bergen Methods" of Weather Analysis, which have developed at the Bergen Institute—thanks to the generous support from the Carnegie Institution—has been characterized by Bergeron as "indirect aerology." Although observations are at hand only from the ground—the direct free-air ("Aerological") observations will always remain

absolutely insufficient—it has been proven possible to work with unexpectedly complete three-dimensioned pictures of what is actually going on in the atmosphere.

The author tries to give the rational foundations of this indirect aerology. From the point of view of principles, but in a form which is either purely mathematical or purely empirical, he tries, through a discussion of the formation of the atmospheric masses of air and of the fronts separating them, to find *all possibly existing essential models of the structure of the troposphere*.

In the first chapter he gives the general principles for profiting from the internal connections existing between the meteorological elements, especially in defining and discussing the representative observations and the conservative properties of the air masses.

In the second chapter he discusses the formation and the identification of the tropospheric air masses, and through statistics on actual air masses he gives proof of the existence of the two defined main air masses—the polar and the tropical air—and of their properties.

In the third chapter he discusses in an analogous way the formation of the fronts separating these air masses. This leads to a discussion of a provisional scheme of circulation for the whole earth, which not only comprises the general polar front, but also all the possible air masses and fronts discussed in the previous paragraphs.

The next part of this paper will be devoted to working out in detail the above-mentioned scheme of air circulation, especially the application of these methods to the theory of tropical hurricanes and monsoons.

4. On account of the great practical importance of the “indirect aerology,” it is highly desirable to utilize every opportunity to verify or to correct the results gained in this way, by submitting them to the control and correction of the direct aerological observations.

An excellent opportunity for this has developed through a collaboration of Mr. J. Bjerknes with M. Jaumotte, director of the meteorological Institut of Brussels. M. Jaumotte has constructed recording aerological instruments which are far cheaper, lighter and more sensitive than the old ones and the plan is, when an atmospheric discontinuity passes, to send up instruments every hour or even every quarter of an hour, in order to get a complete cross-section through the fronts, and thus a complete representation of its field of mass and motion for the dynamical analysis.

As the experiment is made in the most thickly populated part of Europe, almost all the instruments sent up are recovered (in Norway this would be hopeless), and the results of the preliminary experiments seem in every respect to give promise of success.

NUTRITION

Osborne, T. B., and L. B. Mendel, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3-26.)

The third year of experience with so-called "synthetic" rations that have been improved by the addition of comparatively small quantities of "natural" foods agrees with the records in two previous reports, and has abundantly confirmed the conclusion that the optimal possibilities of growth of the albino rat had previously been greatly underestimated. The hitherto published "average" or "normal" rates of growth of both sexes of widely used strains of this species have been demonstrated to be decidedly below the readily obtainable optimum. The sustained excellent gains noted in our later records are in no respect exceptional results. In experiments too numerous to mention here, daily gains of more than 4 grams were usually made during the period of active growth, in contrast to 2 grams or less formerly considered normal. More specifically, whereas the figures most widely found in the literature relating to the growth of rats indicate average daily gains, during the period of increment from 60 to 200 grams of body weight, of 1.77 grams for the males and 1.09 for the females, our newer experiments frequently showed gains above 5.0 and 3.0 grams, respectively, for comparable stages of development. These larger gains are clearly attributable to improved diets and may be regarded as more nearly representative of optimum growth for rats.

The most rapid rates of gain hitherto described for animals of a given size have been observed during periods of *restoration of growth* when this function has been retarded or suppressed by some marked deficiency in the food intake. Thus the range of the ten best records of daily average gain in body weight obtained by us during periods of recovery of approximately one to two weeks may be summarized as follows: Male rats, 6.4 to 7.6 gm.; female rats, 4.9 to 7.0 gm. Even the largest of these daily gains exceed by only a small amount the largest increments of weight noted under our most favorable conditions of *unimpeded* growth. Hence in a recent paper we raised the question whether it is necessary to postulate any *extraordinary* capacity for gain incident to resumption of growth after it has been suppressed. Perhaps the increment of weight under such conditions is merely illustrative of what can take place at any early period of growth, provided the proper food factors are supplied.

It is not without interest to consider the significance of some of the recorded gains in size in relation to the body as a whole. A rat at one-third full adult size, approximating 120 grams in body weight, during an optimal growth of 5.5 grams per day, gains daily 4.5 per cent in weight. A comparable daily gain in a person one-third full grown, i.e. at about 23 kilograms body weight, would amount to a kilogram or more. The human species requires thirty times as long as the rat to reach adult size as well

as to complete the ordinary span of life. Even with due allowance for such retarded "speed" a human gain of 30 grams per day, or 24 pounds per year, would be called for to match the growth rate of the rodent under the conditions of our newest feeding experiments. This suggests that under more favorable dietary conditions the growth of children might be accelerated above that now commonly attained.

It might be expected that the apparent precocity exhibited in growth in these trials would result in earlier sexual maturity. This raises the question whether the development of the various organs keeps proper pace with the rapid growth of the body as a whole. Such breeding tests as we have undertaken have not indicated any tendency to produce young at the early age that might be expected from the size of the rapidly growing rats. However, the records of the age of pubescence are still too variable to permit any final statement. In our experiments males and females were kept on a diet that had demonstrated its efficiency in promoting rapid gains and that contained a liberal inclusion of wheat germ to provide vitamin E. An investigation of the earliest actual onset of the œstrus cycle remains to be undertaken.

A recent study of the rate of growth of infants has indicated that under certain conditions prevailing in human feeding practice, advantage accrues from increasing the allowance of inorganic elements in the food. The question has even been raised as to whether the mineral ingredients in human milk represent an optimal mixture from a quantitative standpoint. We have conducted experiments to ascertain whether an increase in the allowance of inorganic salts to one of our most successful feeding mixtures would bring any nutritive advantage as exhibited in more rapid growth. The food mixtures consisted of—

Casein.....	35	per cent	35	per cent	35	per cent
Salt mixture.....	2.5	per cent	5	per cent	10	per cent
Starch.....	38.5	per cent	36	per cent	31	per cent
Butter fat.....	9	per cent	9	per cent	9	per cent
Lard.....	15	per cent	15	per cent	15	per cent
Lettuce, daily.....	20-40	gm.	20-40	gm.	20	gm.
Liver, daily.....	0.4	gm.	0.4	gm.	0.4	gm.

The inorganic salt inclusions (Osborne-Mendel salt mixture) were kept, as indicated, at 2.5 per cent, 5 per cent and 10 per cent respectively. The growth was rapid in all cases. The individual records were too variable to permit final conclusions. The rations with the two highest contents of salts were essentially comparable in effect during the period of rapid growth. It should be noted, however, that in any event the addition of lettuce and liver to the basal diet made the food mixture comparatively well supplied with inorganic nutrients.

Our attention has naturally been directed to the factors present in the adjuvants—yeast, liver, lettuce, etc.—that have served to make our "standard" diet of protein, fat, carbohydrate and salt mixture so effective in promoting rapid gains in body weight. Such comparisons as have already been made indicate that combinations of the adjuvants, *e.g.* yeast+lettuce, yeast+liver, etc., are in general more effective than is any single one of these natural products. Attempts have been made to ascertain the dosage of

each alone required for the best rate of growth attainable with the food in question. Combination of one-half of such supplemental quantities of each of the adjuvants have frequently, though not invariably, caused better gains than the full dosage of the individual components. For example the combination 0.2 gm. yeast + 0.4 gm. liver afforded better growth than either 0.4 gm. yeast or 0.8 gm. liver as the sole supplement; however, when 0.4 gm. yeast was supplemented with cod-liver oil the results were also surprisingly good. The advantage of the liver additions in these experiments may have been due to the vitamine remaining in the oil of the hepatic tissue. It is extremely difficult to make convincing quantitative comparisons of this sort, hence we hesitate at present to offer any final generalizations. The phenomena reported can best be interpreted on the assumption of at least two vitamin-like factors in the materials that have served as sources of vitamin B in these and earlier feeding experiments. The factors are not distributed in equal amounts in the different food adjuvants used. Consequently suitable combinations would be more likely to supply more nearly optimal proportions of all these dietary essentials. Such an explanation is in harmony with the newer claims that what has hitherto been designated as vitamin B represents in fact at least two different components, vitamins F and G, or B₁ and B₂ as they have been recently designated. This may serve to explain the numerous failures of attempts to secure potent concentrates of vitamin B. The manipulations have doubtless in many cases served to separate the component factors so that one alone was used, whereas all are requisite for perfect growth. It becomes necessary, therefore, to learn the requirements of the rat for each of the components and their relative distribution in natural products. A complete revision of the so-called assay of the vitamin-B complex has become imperative.

The study of protein-free water extracts prepared from fresh liver has indicated that all the essential components of what has been termed vitamin B are present therein. Apparently, however, the proportions of the components are not optimal. Attempts at fractionation have proved disappointing thus far. Incidentally we have found that the commercial preparation of liver extract recommended by the Harvard Committee on the Study of Pernicious Anemia contains the vitamin-B complex.

Several years ago we demonstrated that in starvation the liver of the rat is largely depleted of vitamin B. The finding of apparent differences in the vitamin content of the liver of the calf and full-grown animals (beef, pig) suggested that the vitamin-B content of the diet might markedly affect the storage of the vitamin in the liver. Observations on the livers of rats receiving 40 per cent of potent dry yeast—a good source of the vitamin-B complex—in their rations failed to show any noteworthy superiority over the hepatic tissue of stock animals.

The report of last year gives the formula of a "synthetic" diet suggested for the study of the influence of various dietary modifications on the development and composition of the skeleton and on the rate of growth. It was planned with special reference to changes in the inorganic components of the diet with simultaneous variation of the potential reaction of the ration. The program previously outlined is being resumed. Thus far we have arranged

to secure data on the comparative rate of growth, the content of Ca and P in the blood, the composition of the bones and their histological structure when the level of inorganic salt intake, the ratio of Ca:P in the food, the potential reaction of the latter, the proportional content of protein, fat and carbohydrate, and the intake of the different vitamins respectively are varied.

This year marks the beginning of a direct collaboration with Dr. Francis G. Benedict of the Nutrition Laboratory of the Carnegie Institution of Washington in the study of the respiratory metabolism of the rat. Dr. Benedict has assembled in Dr. Mendel's laboratory in the Sterling Hall of Medicine, Yale University, respiration apparatus designed for the measurement of oxygen consumption and carbon dioxide output in comparatively brief periods of observation. It is intended to investigate at first the possible influence of varying rates of growth or prolonged suppression of growth as the result of various dietary deficiencies on the basal metabolism. The work is in charge of Miss Katherine Horst. Standard conditions for the conduct of the experiments are being developed and will be reported in detail by Dr. Benedict.

The chemical investigations of the laboratory have been largely devoted to a detailed study of the basic amino-acids yielded by proteins, as it is felt that it is imperative to have further knowledge of certain of their fundamental chemical properties. Following the observation that histidine could be quantitatively separated from arginine by a double precipitation as its silver compound at, or near, a hydrogen ion concentration of pH 7.0 we have devised modifications of the procedure originally suggested by Kossel for the estimation of the basic amino-acids.

The method consists in the precipitation of arginine and histidine together as their silver compounds by the addition of barium hydroxide, to a strong alkaline reaction of phenolphthalein, to a solution of the totally hydrolyzed protein containing an excess of silver ion. The precipitate is then decomposed with hydrogen sulphide and the histidine precipitated twice as its silver compound at pH 7.0, the arginine passing quantitatively into the filtrates. For further purification histidine is next precipitated by mercuric sulphate and the quantity estimated from the weight of the dinitronaphtholsulphonate of this base which was referred to in last year's report. The arginine is likewise recovered and weighed as its dinitronaphtholsulphonate. No essential modifications have been made in the method of determination of lysine. As in Kossel's original procedure, the proportion of lysine is determined from the weight of its picrate.

In this way the proportions of all three bases are referred to the weights of definite compounds. This is a marked improvement over the older method in which the proportions of arginine and histidine were calculated from nitrogen determinations in their respective fractions upon the assumption that these fractions were chemically homogeneous.

The technique of silver precipitation has been greatly facilitated by making use of silver oxide as suggested by Kiesel. This reagent is added as a thin suspension to the solution which is maintained faintly acid to Congo red, or brom phenol blue, by frequent small additions of dilute sulphuric

acid. This procedure permits the addition of sufficient silver essentially as sulphate, but avoids the great dilution which would result if this rather insoluble salt were added in aqueous solution. In this way no ion is introduced which can not be subsequently easily removed. When silver nitrate is employed, much labor must be expended in washing the different precipitates free from nitrate ion, since the nitrogen content of the solutions secured by decomposing them is of significance, not only for the calculation of the theoretical content of base but also for calculation of the amount of dinitronaphtholsulphonic acid which must be added. A comparison of the actual yield of sulphonate with that calculated from the nitrogen of the solution gives a measure of the purity of the fractions.

Several analyses of edestin have been carried out which indicate that the results of determinations by this method upon 50-gram samples of protein are approximately 90 per cent of those obtained when a much larger sample (350 grams) is taken for the analysis. This may be interpreted as meaning that the unavoidable losses encountered in the numerous operations affect the results more seriously when small samples of protein are analyzed, and is therefore an argument in favor of the use of large samples of protein for the analysis.

Our best figures, which have been embodied in the paper published in the *Journal of Biological Chemistry* describing the modified method, indicate that edestin yields 2.08 per cent of histidine, 15.8 per cent of arginine and 2.19 per cent of lysine.

Data were also secured, showing that preliminary precipitation of the three protein bases with phosphotungstic acid is not permissible if quantitative results are sought. The solubility of the phosphotungstates of these bases is such that serious errors occur unless the filtrate is subsequently worked over by the silver precipitation method for arginine and histidine.

It has been suggested by Plimmer and Lowndes that the solubility of arginine phosphotungstate may be due to partial racemization, the phosphotungstate of the racemic base being more soluble than that of the active substance. Arginine recovered from a phosphotungstic acid filtrate by the silver procedure showed full optical activity. It therefore seems improbable that Plimmer and Lowndes' suggestion is correct.

The basic amino-acid lysine has not hitherto been prepared in crystalline form. As we were in possession of considerable amounts of different salts of this base it was felt that an attempt should be made to crystallize it. A quantity of lysine picrate was therefore further purified by recrystallization and decomposed with sulphuric acid. After removal of the picric acid and most of the sulphuric acid the free base was liberated by the careful addition of the requisite amount of purified barium hydroxide with due precautions against the access of carbon dioxide. On evaporation of the solution to a sirup, crystallization readily occurred and, by the use of aldehyde-free absolute alcohol, a preparation of the free base crystallizing in hexagonal plates was secured. Photomicrographs of these crystals have been published.

In order to complete our study of the bases of proteins in the free form, highly purified specimens of free arginine and histidine were likewise secured

and photographs published. Arginine was found to separate from aqueous solution in rectangular prisms containing two molecules of water of hydration. From 66 per cent alcohol it separates in thin parallel-sided plates. Histidine separates from water or from 50 per cent alcohol in rosettes of thin plates.

As mentioned in last year's report, the silver precipitation method has been applied to the large scale preparation of arginine from edestin. The procedure is relatively simple and arginine thus becomes one of the more readily available amino-acids. The silver method has likewise been applied to the preparation of histidine from hemoglobin on the large scale, and a paper describing this application is now in press.

Work upon the simpler nitrogeous constituents of yeast has been held in abeyance pending the further development of our methods of analysis. As mentioned last year this material contains an extremely interesting substance which was separated from the histidine fraction in pure form but which has not yet been identified. We hope to pursue the investigation of this material at a later date.

The fundamental problem of determining the nature of the substances in the fluids bathing the active protoplasm of living cells is apparently little nearer solution. Our experience with extracts from a number of tissues has shown that an extraordinarily complex mixture of substances is present. Progress in dealing with the analytical problems presented by such mixtures is necessarily slow. Few of the reagents which must be employed are really specific and each fraction must therefore receive special treatment designed to increase the relative concentration of the particular constituent which is being sought up to the point where direct crystallization of the substance, or a derivative of it, becomes feasible. In order to increase our field of experience with such problems, some time has been expended upon a preliminary investigation of extracts from fresh green tobacco leaves. A number of practical considerations determined this choice. In view of our close affiliation with Connecticut agriculture at this Station and the great importance of the tobacco crop in this state, we felt that work upon tobacco leaves might give results having considerable bearing upon agricultural practice. Moreover the Station is in a position to supply tobacco of almost any variety grown under controlled conditions in large quantities, and we may be assured of a continuous supply of perfectly definite material. The leaf lends itself particularly well to chemical treatment of the type required in our work. Two somewhat difficult chemical problems have already been encountered. Nicotine is present in fresh tobacco leaves in relatively large amounts, and the chemical properties of this substance are such as to interfere seriously with certain of the routine methods of analysis that have been hitherto employed. We hope, however, to be able to surmount this difficulty. The other difficulty has to do with the alleged high concentration of nitrate nitrogen in certain tobaccos. We are not yet satisfied that the indirect methods of analysis that have been employed are trustworthy, and it is planned to subject this question to thorough investigation.

At the request of the editor of *Physiological Reviews* a paper has been prepared, discussing the present status of speculations upon the constitution

of proteins, a matter which has received a great deal of attention, particularly in Europe, during the past few years. So much of current thought is inadequately supported by chemical evidence that we felt it necessary to present the subject from a highly critical point of view. The paper is now in press.

Williams, R. R., and Walter H. Eddy, Teachers College, Columbia University, New York City, N. Y. *Physiological functions of vitamins.*

The following report refers to work undertaken in April 1927 under a grant authorized by the Carnegie Corporation of New York to the Carnegie Institution of Washington for three years' consecutive study, and covers progress to June 30, 1928.

The physiological function of vitamins will probably never be satisfactorily established until we have them in approximately chemically pure form. Isolation is therefore especially important as a first step, and our first year's work was much concerned with this phase of the study. Review of the entire field is obviously beyond the scope of any one laboratory, hence we have limited our endeavors to those vitamins found in yeast and other foodstuffs and which are commonly designated under the term vitamin B or vitamin-B complex. Because of certain chemical and physiological similarities-exhibited by the yeast-growth stimulants designated by Wildier as "Bios" and because of progress already made in this laboratory toward their isolation, part of our work during the past year has been to extend studies of these compounds. In that connection it may be pointed out as justification that we have in these factors chemical growth stimulants of apparent simplicity of structure. Since they act directly upon the single-celled organism, yeast, such factors are, perhaps, a better tool for explanation of growth stimulation than the concentrates which act on the complex animal organism. In this connection it is interesting to note here that Dr. L. H. Gregory of Barnard College has during the year been able to show definite response to certain of our bios preparations by protozoans of the *Dallasia*, *Pleurotricha*, and *Stylonichia* types.

PROGRESS IN BIOS ISOLATION

In December 1924 we first reported the isolation and purification of a crystalline product, melting point 223° C., which showed properties ascribed by Wildier to "Bios." Further study soon demonstrated that the yeast autolysate from which we secured our crystals (alpha-bios in our present nomenclature) was always a more potent yeast-growth stimulant than the crystalline fraction which we had removed. The latter was active but the autolysate, in amounts corresponding to its presumed content of the crystalline entity, was much more active. Other data bearing on the activity of our crystals has also gradually accumulated, among them being the variability in response of test cells with variation in species, previous dietary history, concentration of stimulant, influence of seeding, time of incubation temperature, etc. The description by Miller and Lucas of two Bios concentrates labeled by them Bios I and Bios II and comparison of these fractions with our crystals seemed to indicate clearly that not only were

their products different from ours but, in accord with the idea first advanced by Fulmer, these comparisons definitely supported the view that yeast contains a multiplicity of bioses of distinctly different chemical nature.

Our first step was to try to demonstrate that yeast autolysate contains bioses different from our crystalline product. This was satisfactorily accomplished by electrodialysis. A cell divided into 14 compartments by parchment membranes was devised. When these 14 compartments were filled with a homogeneous yeast autolysate and then submitted to an electric current, a separation of components resulted. By testing the physiological activity of the contents of each compartment and correlating it with the pH of that compartment, we demonstrated that growth-stimulating material had separated into two distinct regions with markedly different pH. A homogeneous solution of alpha bios submitted to similar electrodialysis failed to show such separation. We therefore considered this result as justifying an attempt to locate and isolate a second bios.

The accumulation of sufficient quantity of this second factor by electrodialysis of yeast autolysate presented mechanical difficulties. We therefore experimented with chemical means of accomplishing its fractionation and accomplished the separation of a second substance, quite different in properties from alpha bios and which we designate as beta-bios.

In the process of separating beta-bios, we also demonstrated that there is left after removal of both alpha and beta bios a residue which still exerts yeast-growth stimulation. This concentrate has not yet been further fractionated. It may contain the bioses of Miller and Lucas. The beta-bios was separated by hot precipitation and freed from other impurities with various re-agents. The method will be published in detail later.

The new beta-bios is exceedingly hygroscopic. When dehydrated with acetone and in a vacuum desiccator, it is a fine white granular powder decomposing at 100° C. on prolonged heating. Fused with KOH it evolved ammonia and skatole, the latter even when fused in a copper tube in an atmosphere of hydrogen. Three separate products gave the following elementary analysis:

	C	H	N
Product 1.....	42.76 p.ct.	6.52 p.ct.	6.18, 5.47 p.ct.
Product 2.....	42.58	6.42	...
Product 3.....	42.65	6.60	...

Evidence of homogeneity to date rests on the fact that repeated isolations have always produced a compound with identical physical, chemical and physiological properties. Realizing, however, from the non-crystalline character of the product the difficulty of establishing chemical purity we have attempted to synthesize a compound having what we conceive to be its probable chemical structure. To date we have, starting with synthetic coumarin, succeeded in producing a synthetic product which resembles beta-bios in properties and has physiological activity, the latter, however, of a lower order than the isolated form. Details of this work are reserved for later publication.

The physiological activity of beta-bios and other fractions have been tested by the Funk-Dubin method on six different strains of yeast grown

on varying synthetic culture media and under variations of bios concentration. During the year we have had the volunteer assistance in the Laboratory of G. L. Peskett of the Oxford University, Department of Biochemistry. Peskett has arrived at a theory of "critical concentration" of bios which he expresses as follows:

Each bios to be effective must be present in an amount which is definite for the bios concerned. At this *critical concentration* a small seeding of test cells will in a given time period produce the same crop as a large seeding, while a diminution of concentration so slight as 0.005 milligrams per cubic centimeter produces large decrease in the crop finally attained.

He believes this fact explains divergence in results obtained by different workers in using the same bios concentrate. He further confirmed his viewpoint with our bios fractions and concentrates, and these results were published from our laboratory during the year. The critical concentration of beta-bios appears to be 0.05 to 0.075 milligrams per cubic centimeter producing at least tenfold growth over the control in 48 to 72 hours till incubation at 31° C. Beta-bios is definitely more stimulatory in this time period than alpha-bios, but as incubation time is extended alpha-bios effect increases. Yeast autolysate shows greater stimulatory power than either alpha or beta alone or in combination, thus indicating still other bios entities in the yeast autolysate.

PROGRESS IN CHARACTERIZATION OF VITAMIN B

Knowledge of vitamins of the "B" type took two apparently important forward steps shortly before the initiation of work under this grant. One of these was the formulation of evidence (chiefly from the U. S. Public Health Service) that, besides the antineuritic or beri-beri preventing vitamin, there is present in yeast a second important vitamin credited with prophylactic powers against pellagra. This new view has during the year been confirmed by corroborative work elsewhere. The second step was the reported isolation in pure form of the antineuritic vitamin by Jansen and Donath in Java. No published confirmation of this work has appeared.

Our own work has therefore taken two directions: (1) the differentiation of the constituent physiological entities comprised in vitamin B, and (2) the verification of Jansen and Donath's work in the endeavor to identify (or distinguish) their product physiologically with our own products and with those reported by other workers. These two lines of endeavor are closely related as the question of effectiveness of an isolation procedure often involves a question of the identity of the physiological entity dealt with.

Following the first line of endeavor we have succeeded in preparing from yeast an activated fuller's earth which appears to contain only the antineuritic vitamin.¹ This form of B₁ is made by bringing a small proportion of fuller's earth into contact, through a dialysing membrane, with a hot-water extract of brewer's yeast. The membrane keeps back colloidal substances

¹ In accordance with the present practice of the British workers and pending the action of our own committee on nomenclature, we will designate these distinguishable constituents of vitamin B as B₁, B₂, etc., in what follows; B₁ referring to the antineuritic factor, B₂ to the antipellagric factor as described by Goldberger and B₃ and B₄ new entities which our work has led us to predicate.

tending to destruction of the adsorptive selectivity of the fuller's earth. The active material so obtained is characterized by the fact that it will prevent polyneuritis in pigeons on a polished rice diet, though weight is maintained only at a subnormal level. Alone it also prevents polyneuritis in young rats, and in addition it makes possible normal growth on a classical B-free diet involving extracted casein, provided autoclaved yeast is also added to the diet.

We have also confirmed the existence in yeast of vitamin B₂, described by Goldberger as protective against pellagra symptoms, and have shown that it is of slight nutritional significance to pigeons though of crucial importance for rats. In this respect our work extends the corroborative evidence of Chick and Roscoe and other workers.

We have shown the existence in yeast of a new vitamin which we will call B₃. This substance is apparently of little consequence to rats, but serves when supplemented by B₁ to maintain adult pigeons on polished rice at full normal weight and in apparent health. We have not yet developed a method for isolating this substance in physiologically pure form, but have determined its distribution in several foodstuffs. Brewer's yeast and grains are the richest sources known to date.

In addition we have secured some evidence of the existence of a fourth member of this family of vitamins which we will tentatively designate as B₄. This substance appears to be present in brewer's yeast and also in commercial casein, even after thorough extraction of the casein with 60 per cent alcohol. It is required for the normal growth of young rats, as may be demonstrated by comparing the rate of growth on a classical casein base diet, supplemented on the one hand with our B₁ plus B₂ preparations and on the other by whole brewer's yeast—provided the casein diet is previously thoroughly baked at 120° C. If the diet is not baked, no such distinction is discernible.

Further confirmation of the existence of B₃ and especially of B₄ is required. If secured in the latter case it will serve to clear up a great deal of confusion in the literature and especially the hitherto inscrutable, though apparently rigorous, experiments of Palmer and Kennedy.

In the field of chemical isolation we have repeated the fractionation of Jansen and Donath, using yeast extract in lieu of rice polishings, and fuller's earth instead of their acid clay. We have also secured from Java a supply of their clay and are now in process of repeating the operation with close attention to duplication of their procedure.

The fractionation of yeast by their method failed to yield full confirmation of their results, but did furnish much valuable evidence which we will briefly recapitulate.

The B₁ activity as tested on both rats and pigeons was widely scattered in many fractions, but in each case their selected fractions proved to be somewhat more active than any of the discarded ones until the stage of platinic chloride precipitation was reached. We found that this precipitate was only partly soluble in water and accordingly made a separation at this point, thus introducing a deviation from the prescribed method. Little activity was present in the water-soluble fraction contrary to what we were

led to expect from Jansen and Donath's description of their substance. The water-insoluble fraction, however, showed activity in high concentration, but the yield constituted a very much smaller portion of the total present in the starting material than Jansen and Donath reported in their case. The final fraction possessed the properties of B_1 and not of B_2 or B_3 . Several crystalline substances were separated from the final fraction, but they were all physiologically inert or nearly so.

Many of the fractions corresponding to those discarded by Jansen and Donath at various stages of their process proved to be active with respect to B_3 as well as B_1 . Others contained B_3 only and some B_1 only. In general we found in dealing with yeast extracts, that silver nitrate is a much less selective precipitant for B_1 than Jensen and Donath reported in the case of rice-polish fractionation. Neither is B_3 selectively and completely precipitated by silver nitrate. Phosphotungstic acid precipitates B_1 more completely than B_3 and seems a promising reagent for separating the two. B_2 is largely left behind in the filtrate from the first adsorption operation and thus separated from the bulk of both B_1 and B_3 . The fate of B_4 , if present in the original yeast extract, is as yet entirely unknown.

We have also carried out the fractionation of yeast according to the method of Kinnersley and Peters and tested the product prophylactically. "Torulin," as described by these workers, appears to have predominantly the properties of B_1 rather than those of B_2 or B_3 .

Our immediate task in the B field is to endeavor to confirm the existence of the newest members of the family; to secure B_2 , B_3 and B_4 in physiologically pure forms and to characterize each of the four B vitamins as fully as possible in relation to the nutrition of higher animals. In so doing we may yet find evidence of the existence of still other members of the family at present unsuspected. Some hints as to the significance of B_3 and B_4 for human nutritional disorders are also to be hoped for.

Another line of endeavor of the past year that has yielded results of promise involves a synthetic approach to the problem of identity of B_1 . Some years ago, one of the present group of workers published results of curative tests of a variety of synthetic substances which he believed to possess certain physiological and presumably chemical resemblance to antineuritic vitamin. His results were questioned by reliable workers. Admittedly there was ample room for question on account of the unreliability of the curative test method, as spontaneous cures sometimes occur and as death sometimes ensues in spite of the administration of a veritable natural antineuritic product. Prophylactic tests with the then known synthetics in most instances had little or no influence on the rate of weight loss or the developments of symptoms of disease. The matter has continued to remain an open question for ten years with presumably a declining credence among vitamin workers in the validity of the original results.

The chemical properties of the antineuritic substance isolated from rice polish by Jansen and Donath seemed to resemble those of the di-keto piperazines, and a synthetic study along this line was accordingly inaugurated. Indications have recently been found that the enol forms of certain synthetic di-keto piperazines have a substantial influence on the length of life and

rate of growth of rats over a 60-day feeding period on classical diets free from the antineuritic factor. The keto forms appear to lack this property, thus conforming to our older theory of isomeric change as a factor in the lability of the antineuritic substance. The chemical features associated with the apparent curative activity of the earlier synthetic preparations are also present in the di-keto piperazines. Feeding results to date with pigeons are not convincingly positive, and those with rats, while apparently beyond the limits of experimental error, still lack the excellence obtainable with natural antineuritics. We seem to be dealing with substances kindred to but not identical with the natural product. We are progressing in the direction of preparing and testing other synthetic piperazine derivatives which chemically more closely resemble the antineuritic of natural origin as described by the Dutch workers.

PALÆOGRAPHY

Lowe, E. A., Oxford, England. *Associate in palæography*. (For previous reports see Year Books Nos. 9-16, 19-26.)

The summer months were spent in various continental libraries, collecting material for studies on the oldest Latin manuscripts. A paper embodying the results of these studies was prepared during the autumn and was published early this year in the *Classical Quarterly* under the title *More Facts about our Oldest Latin Manuscripts*. This article is a continuation of the study published in the same journal in 1926; the two combined furnish palæographical observations upon the oldest 150 manuscripts extant, and should serve as the basis of future publications dealing with uncial and half-uncial scripts.

The winter months were devoted entirely to seeing plates of *Scriptura Beneventana* through the press. In order to get new plates ready it was necessary to visit the libraries of Florence, Rome, Monte Cassino, Naples and La Cava. The last two still remain to be visited, as considerations of health rendered it impossible to complete the work before hot weather set in. It is hoped that this will be done in the autumn. Two-thirds of the above-named work, the *Scriptura Beneventana*, is now in press. It is hoped the work will finally see light in 1929. In this connection it is a pleasant duty to express sincere gratitude to the Abbot of Monte Cassino for his more than ordinary hospitality, and to the Librarian of the Abbey for the many and unusual facilities afforded and for his constant readiness to be of assistance to the work. Thanks are also due to the Prefect of the Vatican Library for his generous permission to work during hours when the Library was closed. Similar unusual privileges were gratefully received from the hands of Pastor Leo Ditges of the Cologne Cathedral Library, the Head of the Museum Meermanno-Westraenianum at the Hague and Dr. Büchner of the University Library of Leyden, who was good enough to permit inspection of the manuscripts in the stacks, which saved an enormous amount of time. At Paris, Leyden and Rome small finds were made which will be the subject of later articles. Two articles and three reviews were written and work was begun on the Index of Facsimiles of Latin Manuscripts, which will be submitted to the Institution for publication when finished.

PALÆONTOLOGY

Chaney, Ralph W., Berkeley, California. Research Associate in Palæobotany. (For previous reports see Year Books Nos. 21-26.)

When the systematic study of the Tertiary floras of Western America was begun in 1920, an effort was made to select for consideration those fossil assemblages which were so well preserved as to furnish reliable data regarding their taxonomic relations, which were sufficiently similar to living plant formations to permit deductions regarding their ecologic significance, and which were so situated stratigraphically as to have their age rather definitely established. At this time little was known of the Pliocene and Pleistocene floras of the West, and the Miocene and Oligocene floras of the John Day Basin of Oregon were selected because they most nearly met the requirements above outlined.

Within the past two years there have been discovered in California an increasing number of Pliocene and Pleistocene localities in which fossil plants are available for study. These fossils are so well preserved, especially in the case of the Pleistocene floras, as to indicate the forest conditions along the Pacific Coast during later geologic time with a considerable degree of completeness.

Eleven localities have been studied in which Pleistocene plant fossils are preserved. These extend from Santa Cruz Island, off the coast at Santa Barbara, to a point a few miles north of San Francisco Bay, and include one locality in the foot-hills of the Sierra Nevadas. The fossils occur in sediments which were deposited under conditions essentially like those along the Coast today, and are of fluvial or estuarine origin. The general study of this material has been largely carried on by Mr. Herbert L. Mason of the Botany Department at the University of California, and the wood has been studied by Mrs. Irma E. Webber of the same department. A total of 30 species has been identified, most of which are still living in western America, and all of which have identical or similar counterparts in the modern forests of the Pacific region. The most abundant and wide-spread of these are conifers, of which closed-cone pines, one or more species of *Cupressus* and *Pseudotsuga taxifolia* are most characteristic; dicotyledons represented in the flora include several species of *Arctostaphylos*, *Ceanothus* and *Quercus*.

While these fossil species are closely related to or identical with members of the living forest, their ranges during the Pleistocene were notably different from those of their living relatives. The Pleistocene forest, of which *Pseudotsuga taxifolia* was a dominant, extended as far south as Santa Cruz Island, while the most nearly related living forest has its southern margin well to the north of San Francisco Bay. The fossil flora in the asphalt deposits at Carpinteria reaches its most southward extent at present in the region of Monterey Bay. This southward shifting of the forests of the Pacific Coast during the Pleistocene appears to have been the result of an

extension of the moist and cool conditions which are now confined to the central part of California and northward. With the establishment of modern climatic conditions the southern margins of these forests have been shifted for a distance of 200 to 400 miles northward to their present limits. The advance and retreat of the forests leaves a record of Pleistocene climatic changes with essentially the same accuracy as the invasions of the ice-sheets in other parts of America.

During the past year the Pliocene floras of California have been studied by Mr. Erling Dorf of Princeton University. These have been collected at ten localities extending from Los Angeles to Eureka, and furnish the first extensive data regarding the forests of this age in western America. The work is not sufficiently advanced to permit more than preliminary comment, but there is already apparent a mixture of modern forest types with those now unrepresented in California and whose living counterparts occur in comparatively remote areas. As now understood, the distributional disparities of these Pliocene floras in terms of their living equivalents take an intermediate position between those of the Pleistocene floras and the floras of the older Tertiary. For while the ranges of the Pleistocene species differ from those of the related living species in terms of only a few hundred miles, many of the Miocene and older Tertiary species are separated by the width of a continent from the ranges of the living species which correspond to them. These studies of Pliocene and Pleistocene floras are therefore of particular value from the standpoint of distribution, both during later geologic time and at the present day.

The wide discrepancy between the ranges of early Tertiary species and their living equivalents is especially apparent in the Goshen flora of west central Oregon. This flora has been studied in collaboration with Dr. Ethel I. Sanborn of the Department of Botany of the University of Oregon. The more than 40 fossil species have their most nearly related living equivalents almost equally divided between the Americas and Asia, with the center of their distribution in Mexico in the western hemisphere, and in the Philippines and southern China in the eastern hemisphere. None of the north temperate species, which characterize the Oligocene and Miocene floras of western America, are represented in the Goshen flora, and there is a dominance of sub-tropical types which indicates a considerably warmer climate than that of Oregon today. This is entirely in accord with the evidence of the marine invertebrates in the associated Eocene formations, most of which have their living affinities in the waters of low latitudes. These differences in the climatic and distributional aspects of the Goshen flora are consistent with its comparatively great age. Future studies of the numerous Eocene floras of western America may be expected to throw much light on the early climatic conditions, and to indicate the origins of many of the living forest formations in various parts of the World.

Merriam, John C., and Associates. *Continuation of palæontological researches.* (For previous reports see Year Books Nos. 20-26.)

In course of the past year the furtherance of palæontological researches in the Pacific Coast and Great Basin regions has been advanced by a considerable group of investigators. Dr. Buwalda, with the aid of assistants, has completed the mapping of the Mitchell and Picture Gorge geological sheets in the John Day region of eastern Oregon, in which there are located the type localities and the typical sections of a long series of formations containing a unique succession of extinct faunas and floras. The completion of this work with the coming year and publication of the map will represent an effort extending over thirty years, but always with concentrated purpose directed toward an understanding of the succession of animal and plant life in this region.

Many papers bearing upon the geology and palæontology of the John Day region have already been published by John P. Buwalda, Chester Stock, E. L. Furlong, E. L. Packard, Ralph W. Chaney, and John H. Maxson. Publication of the geological map will for the first time give a complete assembling of all the data relating to this extremely interesting geological story. Detailed studies in geology will be presented in further publications, both on special topics and of monographic type, by Buwalda, Chaney, Stock and Packard.

In conduct of the work in areas under investigation it has appeared that extension of the region to the south and southeast develops additional sections of extreme interest. It is hoped that topographic maps of these areas may be secured in order that opportunity be given to work out the story of the geology and history of life.

In numerous areas of eastern Oregon, southwestern Idaho, Nevada and California, Chester Stock and E. L. Furlong have made palæontological collections at important localities furnishing remains representing the history of the mammals, including such types as the horse, camel, rhinoceros, elephant, and other forms. These studies by Stock and Furlong constitute an important contribution to the history of life in western North America. Covering a similar area with continuing intensification, Dr. Chaney, in association with Mason, Dorf and Maxson, has published an important series of contributions on the history of plants. The work on the plants and the mammals taken together constitutes an increasingly important series of chapters on the history of America.

In other directions, work of Remington Kellogg on the general history and evolution of the groups of marine mammals represented by whales and seals has made contribution unique in palæontological literature. These researches comprise not only studies of details of osteological structure but with this an investigation of the whole structure of the animal, its adaptation to its environment, its geographic range, and its geologic history.

In still another direction the activities of the Institution have been concerned with geological and palæontological work in a study of the outstanding contributions of such regions as the Grand Canyon of the Colorado for interpretation of fundamental questions.

Report of Investigations by J. P. Buwalda

JOHN DAY REGION

During the summer months of 1927 the detailed mapping of the Picture Gorge and Mitchell quadrangles, in the John Day region of central Oregon, was carried to completion. The hundreds of miles of boundaries between formations had previously been traced; but the separation of certain of the formations into units and their cartographic representation on the maps was carried through and a much fuller understanding of the structure of the region secured thereby.

In the Cretaceous area around Mitchell the mapping of about ten conglomerate and shale zones demonstrated very clearly the existence and position of an important east-west fault. This fracture passes through the southern part of the town of Mitchell, but shows no evidence of recent displacement; in fact, little movement appears to have occurred on it since Clarno time. This fault is apparently one of a number which trend somewhat more northwesterly than the Ochoco range which they bound on the north.

Another discovery made during the summer is that little or no Clarno exists in the Picture Gorge quadrangle, in spite of the enormous thickness of this formation in the Mitchell quadrangle, only thirty miles to the west.

Considerable attention was given during the summer to the physiographic history of the region, and many adjoining areas which seemed to hold out promise of yielding pertinent data were examined. An old-age erosion surface was recognized in the western part of the Ochoco range, and a paper describing it and setting forth evidence regarding its age is ready for publication. Its age is tentatively set at post-Mascall and pre-Rattlesnake.

As in most carefully executed field studies the physiographic history, supposedly easy to comprehend, is in the John Day region the most difficult to understand in all its details. The completion of the areal studies emphasizes the fact that it is not possible to gain a complete knowledge of the history of this region through mapping two areas in its midst, even though these areas be unusually representative. It is hoped that the studies completed may be followed by similar area investigations in adjoining territory, in order to secure the additional chapters of the history which are missing in the quadrangles already mapped.

An interesting discovery near the western and last-mapped portion of the Mitchell quadrangle is an area of several square miles of dark-colored slaty shales, unconformable beneath the Clarno formation. These beds are clearly pre-Cretaceous in age. A rather careful search unfortunately yielded no fossils; the lithologic character suggests strongly that the beds are to be correlated with the supposedly Triassic shales so excellently exposed some miles south of Canyon City.

Bernard N. Moore assisted very ably during the entire summer in the field investigation.

EL PASO RANGE

During the fall and winter of 1927-28 a party of three students from the California Institute of Technology, Alex Clark, Lozell Hookway and Burt Beverly, under the general direction of Professor Buwalda, mapped topographically and geographically in considerable detail an area surrounding Ricardo at the western end of the El Paso range in the northern Mojave desert. This investigation brought out certain facts regarding the succession of beds and the lavas, and aided in giving a somewhat more complete understanding of the physical history of this region.

The large-scale topographical map, constructed in the field, with its 25 feet contour interval, demonstrates both the feasibility and desirability of making a good map of this entire region, particularly now that the state is interested in setting it aside for park or monument purposes, in which case it could become a veritable educational center in its display of certain events in the geological history of the desert.

IMPERIAL VALLEY

During the fall and winter of 1927-28 the detailed geological mapping of the Tertiary formations of the Indio hills at the north-west end of the Imperial Valley depression was commenced. This study, carried on in collaboration with Layton Stanton, has as its object the determination of the stratigraphy and structure of this unique district. The hills lie adjacent to the San Andreas Drift and give a clue to the nature of the movements which have occurred on that fault. The sediments, of great thickness, give a lucid picture of the climatic and topographic conditions existing here at the time of their depression.

It is hoped that fossil material, determining the age of these formations, may be secured, so that the physical events and conditions indicated by the rocks, may be given their proper place in the historical chronology.

Initial steps in a similar attack on the Mecca Hills, lying next east, have been taken in collaboration with Hampton Smith. This is in many respects similar to the Indio group; but there is no warrant for thinking that the strata represent exactly the same stage in the history, and a full understanding of this thick and unique section of rocks is clearly desirable if we are to know what happened in the Salton depression in middle Tertiary time.

Report of Researches by Remington Kellogg

During the past season the following investigations have been carried out:

(1) The report on the pelagic mammalian fauna of the Temblor formation near Bakersfield, California, was completed during this period. The greater part of the material studied belongs to the Pacific Oil Company collection in the California Academy of Sciences, and was assembled by Mr. Charles Morrice and Dr. G. Dallas Hanna, largely through the active interest of Messrs. Paul Shoup and M. E. Lombardi. The Temblor fauna is particularly noteworthy, not only because it is the largest fauna of pelagic mammals thus far discovered on the Pacific Coast, but because it includes primitive whalebone whales (cetotheres), delphinoid porpoises, a squalo-

dont, a sperm whale, two pinnipeds, *Desmostylus*, an extinct sea-turtle allied to the recent green turtle, and at least one bird, and a number of sharks.

(2) Reports of whaling companies operating in various parts of the world, stranding records, and published observations of naturalists were critically examined with the view of assembling what is actually known of the migrations of some of the whalebone whales. It was found that some of the whalebone whales, particularly the humpback, the gray whale and the bow-head, follow definite routes in migrating from warm latitudes to the icy waters near the poles. Others apparently travel where they will. Surface temperatures of the water do not curtail the wanderings of the whalebone whales. Nevertheless, water temperatures, nutritive salts and actinity of light do have an important part in providing suitable oceanographic conditions for the propagation of the food of whales. The data obtained from this compilation has an important bearing on the value of the larger fossil Cetacea for purposes of intercontinental correlation of formations in which their bones occur.

(3) A study of the available North American zeuglodont material is in progress, and the collection of the United States National Museum is being critically examined. Field work in Alabama and Mississippi has been planned to supplement the material now available. Preliminary studies have shown that at least three types of zeuglodonts frequented the Upper Eocene Gulf Coastal Sea during Jackson time. *Basilosaurus cetoides*, which attained a length of from 50 to 70 feet, and whose skull measured approximately 5 feet in length, seems to be the largest of these zeuglodonts. This species has lumbar vertebræ with long centra, and the zygapophyses of all the trunk vertebræ, with the exception of the first four or five dorsals, are separated by increasing intervals proportional to the length of the centrum. The second species, for which the name *Basilosaurus brachyspondylus* seems to be available, was likewise a large zeuglodont, although it has short lumbar vertebræ. The short-bodied *Zygorhiza minor* is the third species, and it probably did not attain a length greater than 15 feet. This diminutive zeuglodont had a vertebral column with articulating zygapophyses.

The following papers have been completed but not published:

Pelagic mammals from the Temblor formation of the Kern River Region, California. (For Proc. Calif. Acad. Sci., 200 pages of manuscript.)

Summary of available information bearing on the migrations of some of the whalebone whales. (For the Smithsonian Annual Report, 30 pages of manuscript.)

Report of Researches by Chester Stock

The palæontological field investigations conducted during 1927-1928 were made in cooperation with the California Institute of Technology. During the summer of 1927 the field party consisted of Chester Stock, E. L. Furlong and J. H. Maxson, and the following projects were carried on:

(1) Continuation of the study of the John Day deposits in the vicinity of Haystack Valley on the John Day River, in the region west of the John Day, and at Logan Butte, south of the Crooked River in Central Oregon.

As a result of this investigation further remains of the mammals of the John Day Oligocene fauna were collected and their stratigraphic position and geographic distribution determined. Studies were initiated with a view to determining the environmental facies represented by faunal units found in the field in specific types of deposits. An investigation of this problem should yield important information relating to the conditions under which the John Day deposits accumulated, and should furnish data for the recognition of types of environment in which the John Day mammals maintained themselves.

(2) A study of the deposits and fauna of the White Bluffs Pleistocene in eastern Washington. The field work added materially to the fauna known from this locality, furnishing a more adequate basis for comparison with other Pleistocene assemblages of the West than has been available heretofore.

(3) The discovery of fossil mammal material in deposits exposed in the Crooked River region between Post and Paulina, Oregon, permitting the determination of Miocene age of this formation on the basis of vertebrate evidence. The specimen has been described by John H. Maxson in the publications of the Carnegie Institution.

(4) Further collecting of Pleistocene mammalian and avian remains at Fossil Lake, Oregon.

(5) Discovery of Pliocene vertebrates in beds exposed in Stinking Water Basin, near Drewsey, Oregon.

(6) Discovery of Pliocene mammalian remains near Harper, Marhuier County, Oregon. This fauna includes representatives of the *Spenophalos* group. These mammals are related to the modern prong-horn antelope and have been known heretofore only from the Rattlesnake beds in eastern Oregon and from the Thousand Creek deposits in northwestern Nevada.

(7) Discovery of Miocene mammalian remains in beds presumed to be the correlative of the Payette formation of Idaho and exposed in the basin of Sucker Creek, Malheur County, Oregon.

(8) Discovery of a Pleistocene and a Tertiary mammalian fauna in the vicinity of Rome on the Owyhee River, in Malheur County, Oregon.

During the Spring of 1928, in cooperation with the California Institute of Technology, expeditions were sent to Santa Rosa Island and San Miguel Island, two of the Channel Island group lying off the coast of Southern California, to investigate the occurrence of elephant remains in Pleistocene deposits exposed in these insular areas. Elephant remains were collected at both localities. The material secured on Santa Rosa indicates the presence of a relatively small species of elephant new to the Pleistocene fauna of the western United States. The collections are now being studied in detail and a preliminary report of the occurrence will be published in Science.

Studies relating to the Rancho La Brea Pleistocene fauna have progressed as follows:

(1) A report on the census of the Pleistocene mammals has been completed.

(2) Further advance has been made with the study of the Felidæ and the memoir on this group is nearing completion.

(3) Studies by Dr. Roy L. Moodie on the incidence of disease among the Felidæ of Rancho La Brea, particularly the sabre-tooth cat, have been advanced considerably during the past year.

(4) Illustrations for several monographs dealing with the mammalian groups are in course of preparation by Mr. John L. Ridgway.

Six papers describing Pleistocene and Tertiary mammals of Western North America will appear in Publication No. 393, Carnegie Institution of Washington.

White, David, National Academy of Sciences, Washington, D. C. *Study of the fossil floras in the Grand Canyon, Arizona.* (For previous report see Year Book No. 26.)

The search for fossil plants in the strata forming the walls of the Grand Canyon was continued during the latter part of May and the first three weeks of June, some of the work being closely related to and in cooperation with the work of the Committee of the National Academy of Sciences on the development of the research resources of the Canyon.

The search for additional traces of life in the pre-Cambrian was rewarded by the discovery of 2 or 3 possible forms in the lower part of the Unkar group. One of these is suggestive of a very low type of invertebrate. Additional material of considerable interest was gathered, belonging more or less directly to the type of algal deposit named, though apparently not published, by Doctor Walcott, *Chuarina*.

Some of the lime and iron formations attributed to the work of plants have been photographed, and thin sections have been made, but the proposed solution experiments designed to show, if possible, traces of cell structure, have not yet begun. Meanwhile, additional material has been gathered from several other areas for comparison with the Grand Canyon Proterozoic material.

Some additional specimens showing more clearly the characters of two of the species of plants found last year in the Hermit shale were collected and will be used in the report on the Hermit flora.

The effort to find plant remains in the Supai formation, around 800 feet thick, which underlies the Hermit, was partially successful. *Rivularites* and *Walchia* were found at three different levels, and *Walchia*, associated with *Cordiates* and *Calamites*, was found within 60 feet of the base of the Supai formation. Therefore, though the fossil plant representation is disappointingly meager, it indicates lower Permian age for the entire Supai formation. Efforts to find marine invertebrates, such as might indicate Pennsylvanian age, in the formation were unsuccessful. The alga-bearing nodules of lime found in 1927 in the middle of the Supai appear to represent the waning stages of alga limestone deposition in that formation, for, near the base of the latter, limestone masses sometimes several feet in areal extent and occasionally nearly continuous, so as to form a stratum, nowhere over 2 feet thick, were seen to have been made up of calcite deposited in and about dense bodies of yarn-like algæ. On some of the weathered blocks these algæ resemble skeins of very coarse fiber. The Supai was seen to rest on an erosion surface of the Red Wall limestone

marked by sink-hole topography. A thin stratum, about 60 feet below the top of the Red Wall, was found to be made up largely of peculiar algæ of much larger size than those found in the Supai.

Exhibition slabs covered with interlacing, rope-like casts of marine seaweeds were gathered from Cambrian strata of the Bright Angel shale and from the Muav limestone, both for study and for exhibition in the observation station at Yavapai Point.

A monographic report describing the Permian flora of the Hermit shale has been nearly completed and the plates, about 50 in number, are now being made up.

Wieland, G. R., Yale University, New Haven, Connecticut. *Associate in Paleontology*. (For previous reports see Year Books Nos. 2-4, 6-9, 11-26.)

Sequent to the general reexamination of the entire series of Dakota-Wyoming cycadeoid localities reported last year, extension of field study and collection to other parts of the West, long desired, has been begun. As noted, northwestern New Mexico promised unusual material illustrating the variant monocarpic group, although no specimens whatever had been added to any extant collection.

This summer as the result of extended reconnaissance in the San Juan basin region, fine collections of new cycadeoid and other fossil material have been made. Especially along the flanks of the Chuska Mountain in the Navajo country, there is found to occur in strata about two-thirds of the way up in the Mesaverde Cretaceous a columnar monocarpic cycadeoid of striking size—surely among the most remarkable petrified flowering plants ever recovered.

So far the monocarpic cycadeoids have numbered only six; all being single incomplete specimens from far-separated localities, and more or less of necessity referred to separate species as follows:

- (1) *Cycadeoidea dartoni*, Como (Jurassic), Black Hills.
- (2) *Cycadeoidea fisheræ*, Arundel, Maryland.
- (3) *Cycadeoidea stantoni* (hor. indet.), California.
- (4) *Cycadeoidea masseiana*, "Scaly Clays," Italy.
- (5) *Cycadeoidea nigra*, (hor. indet.), Colorado.
- (6) *Cycadeoidea niobrarensis*, Niobrara chalk, Kansas.

All these "types" have thus been "finds," quite as rare as so many meteorites, with the actual stratum from whence they were derived in no single instance determined. Yet because of the *C. dartoni*, with its series of mature seed cones, the group has seemed most impressive—with of course many unanswered questions as to the nature and extent of the monocarpy present, and the actual floral structures merely inferred. Now, fortunately, the horizon of a giant form is closely located, and abundant material for its study has been secured. The stems reach a full foot and a half in diameter, and may sometimes have been five or seven feet in height, with flowers borne on short peduncles in all leaf base axils and rather small. Among the thousands of more or less complete axes, most of course failing of

terminal preservation, there must surely be some with the stamen and floral structure determinable from thin sections. Small young cones are surely present.

Separation of the monocarpic cycadeoids in a distinct genus has already been suggested, and this now seems a necessity. For the entire group, including the Chuska Mountain specimens, there may best be used the new generic name *Navajoia*. Navajo women brought in or aided in securing most of these specimens, and were the guides to the best localities, having noted those "strange stones" from childhood days while herding sheep and goats. In the preceding list of species, given for the sake of clarity under the old names, *Navajoia* should henceforth replace *Cycadeoidea*. For the new Chuska Mountain type the name *Navajoia magnifica* is appropriate.

In the Mesaverde forest facies, the monocarpic cycadeoids and palms, as evident from remarkable specimens of large size seen in the field, were the dominant types. While in the underlying Mancos, an equally striking horizon, it is probable that the petrified cycads also occur. An Arizona specimen, also the first from that state, with sharp resemblance in form, feature and size to the monocarpic *Navajoia* (*Cycadeoidea*) *fisheræ* of Maryland, comes from the vicinity of the "Wide Ruins," and may be from the Mancos. Obviously, the more immediate continuation of cycadeoid study will center round these new collections, supplementing especially *Cycadeoidea ingens* and *dacotensis*, and the historic *Raumeria*.

Recently the Texas Geological Survey sent a group of *Cycadeoidea* stems from the Trinity beds of that state for identification, which further augments the series from the far Southwest.

An extensive collection of Araucarian and Pinoid stems and cones, made at the Cerro Cuadrado, Patagonia, by Dr. E. S. Riggs, and now in the Field Museum, Chicago, has been intrusted to us for sectioning, for purposes of both exhibition and study. The material indicates one of the greatest of all petrified forests. In the initial section series already made, it is believed there are more well-cut cones than have ever been available hitherto in any of the extinct Coniferales. The age of this singularly fine assemblage of fossils is still somewhat in doubt, but may be Triassic. After this renewed study, it is difficult to escape the conclusion that the Coniferales are a homogeneous unit, and that the Araucarians and Pines are merely two equally old, closely related stocks. A preliminary account of results is given in "Science."

During the past year, continued attention has been given to methods of sawing and cutting petrified plants. The men engaged in the study of the petrified material now receiving notable accessions in a few of the museum and university collections form a lesser but distinct group of investigators with common interests and needs, and it has become desirable to effect-as far as possible interchange or rather helpful interuse, of laboratory facilities.

PHYSICS

Barus, Carl, Brown University, Providence, Rhode Island. *Continuation of investigations in applied interferometry.* (For previous reports see Year Books Nos. 4, 5, 7 to 26.)

Mr. Carl Barus has completed a series of researches with the pin-hole probe and the interferometer U-gage. The apparatus in question is a finely perforated, thin plate or hollow cone, mounted on a quill tube; and it measures the residual nodal pressure or potential energy per unit of volume, at any point along the axis of a stationary sound wave. These pressures, which are thus a maximum at a node and fall off harmonically to zero at an antinode, are naturally small and must be measured by the U-tube interferometer. Progressive waves are without effect on the probe.

When electric induction is treated acoustically by differential telephones, a variety of interesting exhibits appear. Thus, for instance, the phase relations of the two telephones at the end of a pipe may be made to change continuously from reflection without into reflection with change of phase, etc. The experiments indicated the important bearing of electrical resonance phenomena on the work. The coupling of electric and acoustic oscillations was therefore suggested and treated experimentally in a variety of ways.

An endeavor is also made to account for the nature of the activity of the pin-hole probe. Various quill-tube constrictions and length relations are examined. It is shown that even a sliver of thinnest punctured mica has opposed properties on its two sides, in relation to the pressures in stationary waves observed therewith.

The availability of the pin-hole probe in describing the character of the vibrations in larger acoustic apparatus, such as pipes, horns, etc., is indicated.

A variety of incidental investigations, as for instance, on the pressure of the electric wind from a mucronate electrode, on an interference method of measuring the energy of X-rays, etc., were also carried out.

Millikan, R. A., Norman Bridge Laboratory of Physics, Pasadena, California. *Research Associate in Physics.* (For previous reports see Year Books Nos. 22-26.)

The progress made in 1927-28 in the studies carried on in the Norman Bridge Laboratory of Physics on "atomic structure and the nature of radiation" with the aid of the funds provided for that purpose by the Carnegie Corporation is represented in the following forty-nine papers, all published from the Laboratory between July 1, 1927, and July 1, 1928, and all receiving aid in greater or less degree from that Fund. These papers are too extensive for any brief summary, but they may be grouped under the following nine heads and their most conspicuous features pointed out.

(1) The discovery this year at the Norman Bridge Laboratory by Bowen of the nature of nebulium not only solved a century-old riddle, but throws a flood of new light on fundamental atomic processes, so-called metastable states being for the first time shown to be merely long-life-states between which electronic jumps do in time take place. It is then a major discovery that is reported below in the series of papers on nebulium by Bowen. Zanstra's paper makes application of the principles developed by Bowen.

(2) The discovery reported in the series of papers by Millikan and Cameron of the banded structure of cosmic rays is of fundamental significance because it constitutes the first direct experimental evidence of the continuous creation of the common elements out of positive and negative electrons.

(3) The experimental study of new laws governing "field-currents" reported below in papers by Eyring, Lauritsen, Mackeown and Millikan, and theoretically fitted by Oppenheimer into the scheme of interpretation furnished by the new wave-mechanics, represents another major advance. It throws new light on the behavior of so-called conduction electrons in metals. Indeed, it is one of the elements which are now being fitted into the first consistent scheme of metallic conduction.

(4) The precise conditions governing the photo-electric ejection of electrons from atoms are revealed with new completeness, certainty and accuracy in the series of articles listed below by Watson, Loughridge, Anderson, DuBridge and Van den Akker. These constitute another step forward in the understanding of an important and heretofore very obscure field.

(5) Important advances in the spectroscopy, both of the ultraviolet, the visible and the infrared, are contained in the subjoined series of spectroscopic articles by Bowen, Millikan, Badger, Langer and Houston. The last-mentioned author has determined one of the most important physical constants, e/m for the electron, with the highest degree of precision yet obtained anywhere.

(6) Significant theoretical contributions to the new relativity and wave-mechanics are contained in the reported articles by Tolman, Bateman, Zwicky, Robertson and Podolsky.

(7) The problem of the relative motion of the earth and ether has been experimentally solved this year by Kennedy and Illingworth (see below) with the highest precision and certainty anywhere attained thus far.

(8) New light on the laws governing electric discharge and the conditions of reflection of electrons is thrown by the series of papers by Brinsmade, Harnwell, Uyterhoeven and Simon.

(9) The molecular and ionic properties of matter are given applications in the papers by Epstein, Cummings, Richardson, and Brewer, the last of whom has thrown new light on the interaction going on at surfaces between ionization and chemical action.

1. Modification of Gordon's equations. H. Bateman, *Phys. Rev.*, vol. 30, 55-61 (1927).
2. On the reflection of electrons from crystal lattices. F. Zwicky, *Proc. Nat. Acad. Sci.*, vol. 13, 518-525 (1927).
3. Energy relationships and ionization potentials of atoms of the first row of the periodic table in all stages of ionization. R. A. Millikan and I. S. Bowen, *Proc. Nat. Acad. Sci.*, vol. 13, 531-535 (1927).

4. Dynamical space-times which contain a conformal euclidean three-space. H. P. Robertson, *Trans. Amer. Math. Soc.*, vol. 29, 481-496 (1927).
5. The space-distribution of the photo-electrons ejected by X-rays. E. C. Watson, *Proc. Nat. Acad. Sci.*, vol. 13, 584-588 (1927).
6. The relation between temperature and work function in thermionic emission. A. Keith Brewer, *Proc. Nat. Acad. Sci.*, vol. 13, 592-596 (1927).
7. Spectral relationships of lines arising from the atoms of the first row of the periodic table. R. A. Millikan and I. S. Bowen, *Phil. Mag.*, vol. 4, 561-580 (1927).
8. The direction of ejection of X-ray electrons. E. C. Watson and J. A. Van den Akker, *Proc. Nat. Acad. Sci.*, vol. 13, 659-662 (1927).
9. Some factors influencing the ignition of carbon monoxide and oxygen. A. Keith Brewer, *Proc. Nat. Acad. Sci.*, vol. 13, 689-694 (1927).
10. Reflected and secondary electrons from an aluminum target. J. B. Brinsmade, *Phys. Rev.*, vol. 30, 494-500 (1927).
11. Evaporation from lakes. N. W. Cummings and Burt Richardson, *Phys. Rev.*, vol. 30, 527-534 (1927).
12. The velocity and number of the photo-electrons ejected by X-rays as a function of the angle of emission. E. C. Watson, *Phys. Rev.*, vol. 30, 479-487 (1927).
13. Direction of photo-electron emission. Donald H. Loughridge, *Phys. Rev.*, vol. 30, 488-493 (1927).
14. The origin of the nebular spectrum. I. S. Bowen, *Nature*, vol. 120, 473 (1927).
15. The origin of the nebular spectrum. I. S. Bowen, *Pub. A. S. P.*, vol. 39, 295-297 (1927).
16. The symmetry of the stress-tensor obtained by Schroedinger's rule. H. Bateman, *Proc. Nat. Acad. Sci.*, vol. 13, 771-773 (1927).
17. A spectroscopic determination of e/m . William V. Houston, *Phys. Rev.*, vol. 30, 608-613 (1927).
18. A repetition of the Michelson-Morley experiment using Kennedy's refinement. K. K. Illingworth, *Phys. Rev.*, vol. 30, 692-696 (1927).
19. Recent developments in spectroscopy. R. A. Millikan, *Bicentenary Number of the American Philosophical Society's Proceedings*, vol. 66, 211-230 (1927).
20. The electrostatics of the thunderstorm. A. W. Simon, *Jour. of the Franklin Institute*, vol. 204, 617-647 (1927).
21. Two devices facilitating spectrometry in the far infrared. Richard M. Badger, *J. O. S. A. & R. S. I.*, vol. 15, 370-373 (1927).
22. Series spectra of chlorine, Cl_{II} , Cl_{III} , Cl_{IV} , Cl_{V} , and of Si_{II} , P_{III} , and S_{IV} . I. S. Bowen, *Phys. Rev.*, vol. 31, 34-38 (1928).
23. The life of atomic states and the intensity of spectral lines. I. S. Bowen, *Proc. Nat. Acad. Sci.*, vol. 14, 30-32 (1928).
24. Relations of field-currents to thermionic-currents. R. A. Millikan and C. C. Lauritsen, *Proc. Nat. Acad. Sci.*, vol. 14, 45-49 (1928).
25. The origin of the nebular lines and the structure of the planetary nebulae. I. S. Bowen, *Astrophys. Jour.*, vol. 67, 1-15 (1928).
26. New results on cosmic rays. R. A. Millikan and G. H. Cameron, *Nature*, vol. 121, 19-26 (1928).
27. High altitude tests on the geographical, directional and spectral distribution of cosmic rays. R. A. Millikan and G. H. Cameron, *Phys. Rev.*, vol. 31, 163-173 (1928).
28. The photoelectric and thermionic work functions of outgassed platinum. Lee A. DuBridge, *Phys. Rev.*, vol. 31, 236-243 (1928).
29. A modification of the Michelson interferometer. R. M. Langer, *J. O. S. A. & R. S. I.*, vol. 16, 134-136 (1928).
30. The dispersion by hydrogen-like atoms in undulatory mechanics. Boris Podolsky, *Proc. Nat. Acad. Sci.*, vol. 14, 253-258 (1928).
31. On the quantum theory of the Ramsauer effect. J. R. Oppenheimer, *Proc. Nat. Acad. Sci.*, vol. 14, 261-262 (1928).
32. On the extension of thermodynamics to general relativity. Richard C. Tolman, *Proc. Nat. Acad. Sci.*, vol. 14, 268-272 (1928).

33. Transmission and reflection of gold and silver films. W. V. Houston and George Moore, J. O. S. A. & R. S. I., vol. 16, 174-176 (1928).
34. Series spectra of potassium and calcium. I. S. Bowen, Phys. Rev., vol. 31, 497-502 (1928).
35. On the theory of the radiometer (Abstract). P. S. Epstein, Phys. Rev., vol. 31, 914 (1928).
36. Some experiments in positive ion kinetics. Gaylord P. Harnwell, Phys. Rev., vol. 31, 634-642 (1928).
37. On the energy and entropy of Einstein's closed universe. Richard C. Tolman, Proc. Nat. Acad. Sci., vol. 14, 348-353 (1928).
38. On the equilibrium between radiation and matter in Einstein's closed universe. Richard C. Tolman, Proc. Nat. Acad. Sci., vol. 14, 353-356 (1928).
39. The space-distribution of the photo-electrons ejected by X-rays. E. C. Watson, Phys. Rev., vol. 31, 728-741 (1928).
40. Field currents from points. C. F. Eyring, S. S. Mackeown, and R. A. Millikan, Phys. Rev., vol. 31, 900-909 (1928).
41. On the quantum theory of the autoelectric field currents. J. R. Oppenheimer, Proc. Nat. Acad. Sci., vol. 14, 363-365 (1928).
42. Temperatures of stars in planetary nebulae. H. Zanstra, Nature, vol. 121, 790-791 (1928).
43. New precision in cosmic ray measurements; yielding extension of spectrum and indications of bands. R. A. Millikan and G. H. Cameron, Phys. Rev., vol. 31, 921-930 (1928).
44. Series spectrum of sodium, Na_{II} . I. S. Bowen, Phys. Rev., vol. 31, 967-968 (1928).
45. Ionization in positive ion sheaths. Philip M. Morse and W. Uytendhoeven, Phys. Rev., vol. 31, 827-832 (1928).
46. Evidence for the continuous creation of the common elements out of positive and negative electrons. R. A. Millikan and G. H. Cameron, Proc. Nat. Acad. Sci., vol. 14, 445-450 (1928).
47. The pure rotation spectrum of ammonia. Richard M. Badger, Nature, vol. 121, 942 (1928).
48. The equation for the transverse vibrations of thin rods. H. Bateman, Messenger of Math., vol. 57, 145-154 (1928).
49. Transverse seismic waves on the surface of a semi-infinite solid composed of heterogeneous material. H. Bateman, Bull. of Am. Math. Soc., vol. 34, 343-348 (1928).

Nichols, E. L., Cornell University, Ithaca, New York. *Report on studies in luminescence.* (For previous reports see Year Books Nos. 4 to 26.)

POLARIZED FLUORESCENCE

Mr. Merritt has in progress a spectrophotometric study of the polarized fluorescence that has been observed in solutions of certain organic materials in viscous solvents. The immediate purpose of this work is to determine whether the amount of polarization is the same in all parts of the fluorescence spectrum or whether it varies with the wave-length; the few measurements that have thus far been made (Weigert, Wawilow) having led to contradictory results. The question is significant because of its bearing upon the development of a theory of the phenomenon. A theory proposed by Merritt to account for certain relations between fluorescence and absorption¹ is capable of being extended so as to account for polarization; but the exact form which the theory must take will depend upon the way in which the polarization depends upon the wave-length. It is hoped that the experiments

¹ E. Merritt. Phys. Rev. (2), vol. xxviii, p. 684 (1926).

in progress will not only determine the manner in which the theory is to be developed but will also give a quantitative check on its correctness.

FURTHER STUDIES OF URANIUM AS AN ACTIVATOR

The uranyl salts are remarkable, not only for the symmetry of their narrow-banded spectra, the structure of which is unique, but because, so far as known, they do not owe their luminescence to any extraneous activator. Recent observations¹ have shown, however, that in certain other solids, not in themselves luminescent, traces of uranium may be introduced, producing fluorescence. We have found sodium fluoride, thus activated, to be one of the most brilliant of luminescent materials. Miss Slattery is making a further study of uranium as an activator. In this work over seventy colorless, fusible substances were prepared, the procedure being to add a small amount of UO_3 to the molten bead, and to continue the heating until the uranium oxide was dissolved. Under excitation by ultra-violet radiation the following were found to give fluorescence:

Fluorides of Na, Li, K, Rb, Cs, Ca	Chlorides of K, Sr, Ca
Sulphates of Pb, K, Na, Sr	KI and KBr
Borates of Na, K	Potassium silico-fluoride
Carbonate of K	Potassium titano-fluoride
Phosphates of Zn, Na, K, Li	Zinc nitrate

The spectra of the fluorides when excited at -180°C . were resolved into narrow line-like bands. These occupied distinct but slightly over-lapping regions corresponding to the colors of fluorescence of salts, *i.e.* green for LiF , yellow for NaF , and orange for KF .

The bands for all three salts were found to be members of the same three sets with a common frequency interval of about 17.5 (which is the Tanaka interval for uranium), a result in striking confirmation of our earlier observations upon the rare earths; *i.e.* that the frequency interval and location of bands is determined by the activator and is independent of the nature of the solvent.

The spectra of the fluorides in which uranium oxide has been dissolved are quite different in appearance from those of the fluorescent uranyl salts, while all the other substances given in the foregoing list have spectra of the uranyl type. It is thought that in these cases no true solid solution is formed but that a trace of some uranyl salt is produced.

THE SPACE LATTICE

Determinations of the space lattice by the well-known method of X-ray photography with powdered crystals were made of sodium fluoride and lithium fluoride, but no difference in structure between the pure non-fluorescing fluorides and the uranium bearing, highly fluorescent samples could be detected. When mixtures of LiF and NaF in varying proportions but with like amounts of the activator were photographed, the diffraction lines due to LiF were unchanged, but there was a shift of the NaF diffraction pattern indicating shrinkage. It was as though the lithium fluoride penetrated

¹Nichols and Slattery, Jour. Opt. Soc. Am., vol. XII, p. 449 (1926).

the lattice of the sodium fluoride crystals, reducing the distance between atoms, whereas the apparently larger sodium atoms produced no change in the LiF lattice.

An interesting parallel is seen in the fluorescence of this mixture at -180° C. The spectrum extends from the orange to the blue-green, including the wave-lengths found in the fluorescence of each of the separate components. But in the yellow region, where the spectrum from the NaF occurs, there is a blurring of the lines, a widening and a general displacement, together with strong continuous radiation. In the green and blue-green regions, however, the LiF lines appear fine and undisturbed.

Quantitative measurements are now in progress to determine if possible the relation between the amount of shift of the lines in the fluorescent radiation from NaF, and the amount of change in the lattice size when LiF is used to produce the shrinkage.

FREQUENCY INTERVALS OF FLUORESCENCE AND ABSORPTION

In our earlier measurements of the spectra of the uranyl salts,¹ a somewhat perplexing change in the frequency interval was found to occur in passing from fluorescence to absorption. In the intervening portion of the spectrum (the so-called reversing region), where the two effects overlap, there are nevertheless many coincident bands. Miss M. A. Ewer is now making a critical investigation of the data with especial reference to the frequency intervals and to the application of the principle of essential identity to the fluorescence spectra and the absorption spectra of these salts.

MISCELLANEOUS

CERTAIN TEMPERATURE EFFECTS

Mr. J. R. Jenness is studying the effect of change of temperature upon the fluorescence spectra of some neutral organic substances dissolved in alcohol. The spectra are photographed and the negatives are plotted on a greatly enlarged scale by means of the microdensimeter. He finds that as a rule the bands shift to shorter wave-lengths as the temperature is lowered, but that in the case of rhodamin B the shift is toward longer waves.

ANOMALOUS BEHAVIOR OF OXIDES

It was found in our investigation of certain oxides sublimed in the electric arc² that CaO, SiO₂ and ZrO₂ when excited by cathodo-bombardment fluoresce at comparatively high pressures. In a vacuum tube, as evacuation proceeds, they begin to glow, reach a maximum, decline in brightness, and become inert before the pressure is sufficiently reduced to bring other substances to appreciable fluorescence.

Under the conditions of the experiment it was not certain whether these oxides were activated only by cathode rays of low velocity, or only in the presence of traces of free oxygen, or exclusively between definite limits of atmospheric pressure. Mr. D. T. Wilber is repeating the observations with

¹ Carnegie Inst. Wash. Pub. No. 298 (1919).

² Nichols and Wilber, Phys. Rev. (2), vol. xvii, p. 707 (1921).

a hot cathode as source of excitation to decide definitely the nature of the effect.

SUBMERGED COMPONENTS IN CONTINUOUS SPECTRA

Photographs by Boardman of the filament of a tungsten lamp in quartz bulb when measured upon the microdensimeter revealed many systematic irregularities corresponding in position to the line-like bands of thorium oxide. Owing to the difficulty of interpreting such records where the submergence of minor components is nearly complete, this result is being checked by Mr. H. L. Howes with a greatly improved apparatus. If confirmed, it is proposed to extend the study to other incandescent oxides throughout the range of temperatures at which they are known to show cathodo-luminescence.

PHOTO-ACTIVE CELLS WITH FLUORESCENT ELECTROLYTES

A peculiar property has been attributed¹ to photo-active cells with fluorescent electrolytes whereby the current is independent of the external resistance of the circuit. Mr. C. C. Murdock and Mrs. Murdock have shown that this is not the case.² Varying the resistance through a range of 0 to 70 megohms, the current was found to vary in such a way that its reciprocal was a linear function of the resistance. The effect was the same for the photo-active current and for a current produced by an external electromotive force. The apparent invariance has been due to the small resistances which have previously been used. The phenomena may be satisfactorily explained as the result of the polarization of the electrodes and does not seem to be peculiar to fluorescent electrolytes. The photo-active current in the steady state is simply the residual current produced by the polarization of the cell by an internal photo-electromotive force. To test this theory the characteristics of the cell were studied while the electrolyte was subjected to a vigorous stirring to facilitate depolarization. The results confirmed the polarization theory.

The apparatus designed for the above experiment has been utilized further to investigate the location of the electromotive force in the Goldmann type of cell, in which the fluorescent electrolyte is illuminated through a transparent electrode.³ In this experiment the electrolyte was made to flow over the surface of the electrode, under conditions which made possible its illumination before contact with the electrode, during contact or after contact, as desired. The results were in complete agreement with the theory that the electromotive force is largely if not entirely due to action of the light on the electrolyte in which the electrode plays no active part. The investigation is being continued by Mr. W. N. Lowry in order to learn if there is any part of the electromotive force for the production of which the surface of the electrode must be illuminated.

THE NEW MONOGRAPH ON CATHODO- AND CATHODO-LUMINESCENCE

Work on the new monograph by Nichols, Howes and Wilber is now completed. It brings into a single volume the researches of a decade.⁴

¹ Goldmann, *Annalen der Physik*, vol. XXVII, p. 449 (1908).

² Murdock and Murdock, *Trans. Faraday Soc.*, vol. XXIII, p. 593 (1927).

³ C. C. Murdock, *Proc. Nat. Acad. Sci.*, vol. XII, p. 504 (1926).

⁴ Carnegie Inst. Wash. Pub. No. 384.

Committee on the Study of the Physical Features of the Surface of the Moon. Progress Report for the period July 1927 to June 1928.

In approaching the problem of the origin of the surface features of the moon, the Committee has felt that progress can best be made by ascertaining:

- (1) The composition and character of the materials exposed on the surface of the moon.
- (2) Their behavior under lunar surface conditions.
- (3) Their detailed physiographic relationships.

Information on these topics will contribute much to an understanding of the genesis of lunar surface features. Selenologists have been engaged for several centuries in a study of these features; but, thus far, they do not know definitely how any single feature was formed. Many hypotheses have been advanced to account for the observed relationships; but no hypothesis has been universally adopted. This is due primarily to our lack of knowledge of the materials on the surface of the moon and of their behavior under the conditions that exist there. No real advance can be made until more definite information has been obtained. For the present, therefore, the Committee is engaged in making measurements and gathering the data needed.

The task of ascertaining what the surface materials of the moon are is not an easy one, because the only method at present available is to measure the effects produced by these materials on sun's rays, on reflection, and to compare these effects with those produced by terrestrial materials under similar conditions. The effects are of two kinds: (1) Selective reflection or changes on reflection in the relative intensities of light of different wave-lengths; also changes in the total amount of light reflected at different angles of incidence; (2) Degree of polarization for different angles between incident and reflected rays and for different wave-lengths.

During the past year methods and apparatus have been developed for measuring the degree of polarization and the intensities of sunlight reflected by the moon and by terrestrial materials. The apparatus includes: (a) A new ultra-violet spectrograph suitable for use on the 60-inch and the 100-inch telescopes; (b) A new grating spectrograph for use either on a telescope or directly with terrestrial materials; (c) An attachment (Wollaston prism or calcite plate) for use in either quartz or grating spectrograph for the taking of two simultaneous spectrograms, the one by light vibrating in the plane of incidence and the second by light vibrating normal thereto. By first taking an ordinary spectrogram and a comparison spectrum from a standard light source, and then, after insertion of the polarizing attachment, taking the two spectrograms from any selected point on the moon's surface, the observer has a record on his plate from which he can ascertain, for any wave-length, by direct measurements, the total amount of light reflected and the degree of polarization for a given angle between incident and reflected rays. (d) A series of five ray filters of optical glass 8 by 8 inches of measured transmissivities for use in a special 8 by 10-inch plate-

holder with focal plane shutter on the 100-inch telescope. Additional ray filters of smaller size for use on the small 6-inch telescope. (e) A new vacuum thermoelement with fused quartz window made at Mount Wilson and sent to Washington, where it is being used with a high sensitivity galvanometer in the measurement of light reflected and polarized by terrestrial materials. (f) A new 6-inch reflecting telescope tube with fused quartz mirrors for the study of sunlight reflected by the moon and by terrestrial materials. (g) Two 12-inch reflecting concave mirrors of 67.5 feet focus for use in transforming moon photographs for map-making purposes.

During the past year an extended series of measurements has been made in Washington with the polarization photometer eyepiece on the degree of polarization of light reflected, under different angles between incident and reflected rays, by 100 different rocks and terrestrial materials. The results for each substance have been plotted in a series of curves that enable the observer to read off directly the degree of polarization for any angle between incident and reflected beams. A start has also been made to repeat the series of measurements on the same set of materials, using, instead of the polarization photometer eyepiece, the new vacuum thermocouple together with a polarizing prism and different ray filters of known transmissivities.

Photographs of the moon have been taken at Pasadena through a silvered 6-inch quartz lens and through different ray filters to ascertain the areas on the moon's surface that show most pronounced differences in selective reflectivity. These areas will then be studied in detail with the aid of the large telescopes on Mount Wilson.

Each member of the Committee has been furnished with a series of 25 selected 8 by 10-inch photographs of the moon at different phases, for the purpose of study of its physiographic features. A series of transparencies has also been made from the negatives of this series, all reduced to the same scale, lunar diameter 15 inches. These are to be transformed to the same line of sight, and to serve then as a basis for the construction of a new photographic map of the moon.

By measurements and comparative studies of this kind, the background of knowledge is being accumulated that is essential to a just appraisal of the many hypotheses that have been advanced to account for the origin of the surface features of the moon. Until this basis of definite fact is available, no real test of any hypothesis can be made and the matter must rest, as heretofore, chiefly one of personal opinion.

W. S. ADAMS
J. P. BUWALDA
A. L. DAY
P. S. EPSTEIN
F. G. PEASE
H. N. RUSSELL
F. E. WRIGHT (*Chairman*)

PSYCHOLOGY

Gault, Robert H., Northampton, Massachusetts. *Studies on the Psychology of Touch.*

Funds have been provided by the Carnegie Corporation of New York to the Carnegie Institution of Washington in support of this project.

The name of the Vibro-Tactile Research Laboratory suggests that its activities relate to the sense of touch—especially to the tactual qualities of objects that are in vibration. Specifically its objects are: (A) to find what characteristics of speech can be detected through the skin—through the sense of touch or the more problematic independent sense of vibration, or both. (B) To find to what extent these felt characteristics of speech can be made use of to aid the deaf: First, in receiving and interpreting speech and, second, in improving their own art of vocal expression, or spoken language.

The laboratory has the inestimably valuable aid of Bell Telephone Laboratories. Their engineers have designed and built instruments for carrying the energy of speech to the tactual organs to enable our subjects—even a group of them simultaneously—to feel a speaker's words and sentences, and to obtain sufficient distinctions among the feels to make it possible for one to learn to recognize some of the characteristics of spoken language.

Prior to September 1, 1927, the Laboratory had already made a number of important demonstrations, among which are the following:

- (1) In our conditions, subjects can detect, tactually, a vibrational frequency as high as 2600 d.v. a second.
- (2) 18 of 22 subjects have demonstrated their ability to learn to recognize tactually ten vowel and diphthongal qualities up to 83 per cent of a perfect score. This has been accomplished in from 12 to 23 laboratory sessions of 45 minutes each, and by means of a single unit receiver with a natural frequency of 800 d.v.
- (3) Subjects are able to distinguish consonants by pairs after long *e* as follows: p, t, d, l, r, k, m, n, ng.
- (4) Isolated words are more easily learned by touch than vowel, diphthongal and consonantal qualities.
- (5) Still more easily sentence patterns can be identified and memorized.
- (6) Two extensively practiced subjects have been able to interpret a new story of 250 words when they had nothing but tactual criteria to guide them.
- (7) The sense of touch as employed in this laboratory is useful in improving the vocal expression of deaf mutes.
- (8) By the cooperation of 14 deaf subjects, this Laboratory had shown that dual simultaneous stimulation (the *feel* of speech upon the fingers plus *vision* of the speaker's face) enables the subject to interpret speech more successfully than he can do when, as a lip-reader, he depends alone upon seeing the speaking face.

ACTIVITIES OF THE LABORATORY SINCE SEPTEMBER 1, 1927

Since September 1, 1927, the Laboratory has repeated experiments referred to above under 5, 7 and 8; conditions have been reexamined and certain new problems have been undertaken in line with our program.

I. TACTUAL PATTERNS

We have determined the tactual patterns of six vowel qualities (*e—eel*, *er—refer*, *oo—boot*, *o—rote*, *a—father*, *aw—awl*) as obtained through the five-unit teletactor that has been furnished by Bell Telephone Laboratories. These patterns are so distinct that they can be learned much more easily than patterns of the same vowels obtained through the single unit teletactor. The results of this study have been published in the *Journal of General Psychology* (I, 2, pp. 353-359, April 1928).

II. RELATIVE SENSITIVITY OF FINGERS

With a view to shedding light upon a possible rearrangement of units in the five-unit instrument, we have determined the relative tactile thresholds of the thumb and fingers of the left hand. For the purpose, we used the oscillator as a source of energy and selected four vibrational frequencies: 200 d.v., 400 d.v., 800 d.v., and 1200 d.v. a second. The single unit receiver, the diaphragm of which has a natural frequency of 800 d.v., was held in the left hand of the subject. A hearing subject—and only one—was employed in this work. He made a total of 3,840 judgments. The threshold for the thumb and each finger was obtained in terms of resistance dial settings on the oscillator.

Our subject found his index finger most sensitive and there follow in order, the middle finger, thumb, little finger, and ring finger. The middle finger and thumb are so close together that they may be regarded as practically equal.

If these results were borne out by further work of the same nature, it will appear that in any future re-distribution of units in the instrument, the lower frequencies, that are most easily detected, should be assigned to the least sensitive digits.

III. DETECTION OF ACCENTED SYLLABLES VIA TACTUAL SIGNS—AN ANALYSIS OF 10,140 JUDGMENTS

We composed thirteen nonsense syllables combining as many different vowels respectively, with *l* and *s* (such as "*loos*," "*laws*," etc.). Each of the thirteen was then combined with itself and with every other of the nonsense syllables to form a group of nonsense bi-syllables (such as "*loos-loos*," "*loos-laws*," etc.). In the course of the experiment, each bi-syllable was pronounced into the teletactor with emphasis now upon the first syllable and now upon the second. It was the task of the subject to report which syllable had the accent. Only one subject was employed in this work. Three instruments were compared: our single unit teletactor, one unit alone of the multiple unit teletactor, all five units of the five unit instrument working in unison. The subject's 10,140 judgments were divided equally among these three instruments. He was successful in detecting accent as

follows: with the single unit instrument, 91.8 per cent; with one unit alone of the multiple unit instrument, 85.2 per cent; with all five units of the five unit instrument working simultaneously, 87.9 per cent.

We have arbitrarily called seven or more detections of accent in ten trials a satisfactory score. On this basis, the subject's record becomes: 96.7, 84.3, 92.6 per cent on the three instruments, respectively. Since these figures were obtained, we have shown that our deaf subjects *can not approximate this record by lip-reading*. This is an important point in relation to our work on dual stimulation as an aid in the interpretation of speech. If subjects can get accent through touch more accurately than through vision of a speaker's face, we have one very small bit of an answer to the question as to how it comes about that dual stimulation secures better interpretation than stimulation of the eye alone, as in lip-reading.

IV. DISCRIMINATION OF HOMOPHENOUS WORDS

Under this title, the Laboratory has brought together and analyzed a considerable amount of data that had been accumulated prior to 1927-1928. No new experimentation has been undertaken within the year upon the subject in hand. Homophenous words are those that look alike upon the face of a speaker. The lip-reader should not be able to distinguish them when they are spoken in isolation from sentence structure. Illustrations are: *grand* and *grant*. There are upwards of 2,000 such words in the English language. They occur in pairs, in triplets and in other groups as large as a dozen together.

We have worked upon 102 groups of such words. The problem was to discover what kind of record deaf subjects can make in their attempts to distinguish members of such groups as these *by touch alone*, and to compare this with their lip-reading record *on the same material*. There are only 8 of the 102 groups with which subjects did not make a better record by touch than by lip-reading. In two of the eight cases, the score was equal by touch and by vision. In all the records of four subjects, out of 389 cases, there are only 80 exceptions to the general rule that in relation to these homophenous words, our subjects make a higher record by touch than by lip-reading.

Undoubtedly there are groups outside our 102, members of which can not be discriminated by touch. And among non-homophenous words, there are doubtless many groups, members of which can be discriminated easily by a good lip-reader, but by touch, only with great difficulty. But this consideration, together with the analysis of data referred to here, only emphasizes the point that touch and vision supplement each other. Some of the signs by which the sense of touch assists the subject in this connection are set out by the writer in the *Journal of Abnormal Psychology and Social Psychology* (XXII, 1, pp. 33-39, April-June 1927).

V. PATTERNS OF CONNECTED SPEECH AS MEANS OF IMPROVING VOCAL EXPRESSION OF LANGUAGE

We have been successful during the year in respect to improving the intelligibility of the speech of our semi-mute subjects. The gist of the

method consists in requiring the subject to do his best at reading—silently or aloud—in unison with the experimenter who is reading aloud into the teletactor. The subject feels his voice. He holds in his hand a duplicate copy of the story that the experimenter is reading. He follows it with his eye and, by dint of his sense of touch, he keeps pace. Such exercises are coupled with conventional training in enunciation. The theory is that by reason of much feeling of the patterns of speech, its accent, emphasis, rhythm and varying tempo, and by associating it all with meanings, one will develop the implicit as well as explicit responses that together make up the motor aspect of the language attitude and that go a long way toward making good performance semi-automatic.

The Laboratory is attempting to devise a method whereby we may measure the progress of improvement in the intelligibility of speech. We are not entirely successful on this score. Such objective evidence as we have of improvement of our subjects in this relation is supplemented by voluntary statements that have been made by friends, neighbors and physicians.

VI. TACTUAL CUES AS AIDS TO THE LIP-READER

Simultaneous visual and tactual stimulation arising from spoken language facilitates interpretation. This statement assumes that subjects have had appropriate laboratory training to acquaint them with the tactual patterns of spoken discourse and with the feel of at least a few vowel and consonantal qualities.

To the present, the Laboratory has made 84 attempts to demonstrate the effect of simultaneous visual and tactual stimulation when single words in isolation from sentence structure were employed as stimuli. Seventy-seven of these attempts have been successful. This result holds the promise of usefulness in schools for the deaf and in all relations in which deaf subjects are in face-to-face communication with speaking people; for dual stimulation, in our laboratory, gives our subjects an advantage over the straight lip-reading situation upwards of 100 per cent. The median advantage is 30 per cent. How great the advantage may be depends in part upon how proficient the subject is at the outset as a lip-reader. Obviously, if one can perfectly interpret speech as a lip-reader, no device will bring improvement.

It is the conviction of those who have worked in this laboratory that the tactual element in these experiments makes a contribution *in its own right* toward the interpretation of speech. It carries the patterns of speech (made up of rhythm, accent, emphasis, changing tempo and pitch) more satisfactorily than visual cues alone can bring them to the lip-reader. The tactual element, besides, affords a pleasurable reaction that, in our situation, has not worn off even after a whole year of almost daily laboratory exercises.

Notwithstanding the overwhelming evidence that the tactual element in our situation increases facility in interpreting speech, the Laboratory embarked in April upon a program of control tests for the purpose of answering more fully than we have done to date, the question whether the tactual factor contributes *in its own right or indirectly*. We have preliminary data from these tests, as follows, and further results are forthcoming.

TEST I—*In the dual stimulation situation, does the teletactor help the subject to interpret speech merely by furnishing a distracting or accessory stimulation?*

An affirmative answer to this question will receive some support if a lip-reader can surpass his normal record as an interpreter of speech under the following conditions: An experimenter reads certain sentences for the subject to interpret as a straight lip-reader. While this is going on, he holds the teletactor in his fingers and a second experimenter, behind a screen, pronounces into the instrument a series of sentences that have no relation to those that are being pronounced by the first experimenter. Such a situation comprises a series *with distraction*. Eliminate the second experimenter and we have a series in which the subject, as a lip-reader, is interpreting *without distraction*. In which case can he interpret the more successfully?

When isolated words are the stimuli, we have obtained the following results: with distraction, 32 per cent of complete interpretation; without distraction, 41 per cent of complete interpretation.

When *sentences* are being pronounced and scoring is based upon the number of words recognized, we have results as follows: with distraction, 30 per cent of all words; without distraction, 47 per cent of all words.

There is no evidence here that tactual stimulation *as mere distraction* contributes toward interpretation of speech.

This same subject, receiving a group of 100 isolated words as a straight lip-reader, interpreted 39 per cent of them. But when the tactual stimulus was added, from the same words she made a record of 51 per cent. Of 436 words in 50 sentences, she interpreted 48 per cent as a lip-reader and 61 per cent as a lip-touch-reader.

TEST II—*Can one not beat out the patterns of sentences with a moving finger and communicate them visually to deaf subjects much more successfully than can be done by means of the teletactor?*

This Laboratory makes much use of the teletactor as a means of acquainting subjects with the patterns of spoken language.

To test the above question, we have selected from our lists three pairs of sentences, the members of which are alike in gross pattern, and a group of four, all of which are alike. All of these together make a group of ten.

Each of three subjects was given an opportunity to make forty identifications of these ten sentences by their pattern as seen (now one and now another presented by finger wagging) and forty identifications of the same sentences by their pattern, as felt through the teletactor, with the following results.

Subject	Finger Wagging	Teletactor
E	32.5 p. ct.....	67.5 p. ct.
J	45	72.5
S	40	77.5

In the same manner, we have taken alone the four sentences, all of which are alike. Each subject had 40 opportunities to identify as before.

Subject	Finger Wagging	Teletactor
E	27.5 p. ct.....	72.5 p. ct.
J	37.5	62.5
S	37.5	80

However, even if finger wagging should prove to be somewhat superior to the use of the teletactor, we should still prefer the latter because we are trying, in this connection, only to help the lip-reader. Finger wagging will distract the subject's attention from the face of the speaker; a result that can not be tolerated.

TEST III—*Is it not probable that superior interpretation by lip-touch-reading may be due to the fact that the teletactor acquaints the subject with the number of syllables that are being spoken?*

The teletactor makes no such contribution in our laboratory tests, for in our experiments employing isolated words, *all words are of one syllable*. In experiments employing sentences as stimuli, the scoring is based upon the words contained in the sentences. There are 1,026 words, *925 of which (over 90 per cent) are of one syllable*. There is an exceedingly slender chance that acquaintance with the number of syllables being spoken could be of the slightest aid here.

Incidentally, detection of the number of syllables being spoken is much more accurate by means of the teletactor than by lip-reading—according to preliminary tests. For our purposes, 80 sentences were chosen. They were unfamiliar to our subjects and contained 890 syllables. They were presented to the subjects both via the teletactor and visually for lip-reading, and the following proportions of syllables were detected:

Subject	Via lip-reading	Via teletactor
E	24 p. ct.....	40 p. ct.
J	25	46
S	35	60

E and J are mediocre lip-readers and S is fair according to our rating. As far as these results go, they make it clear that the teletactor is superior to the lip-reader's vision as an instrument for acquainting with syllabication.

TEST IV—*Which offers the better means for detecting the accented syllable in polysyllabic words: the teletactor or the visual cues obtained by the lip-reader?*

In a brief series (52 judgments), we have tried to obtain an idea as to how successfully three deaf subjects can detect accented syllables by lip-reading. For the purpose, we made use of the following nonsense syllables: lōos, lōos, lōs, laws, lūs, lēs, līs, las, lers, lēs, lās, lars, lahs. Each of the first four of these, in turn, was taken in combination with itself and with every other one to make a grand total of 52 nonsense bi-syllables.

In the same connection we have undertaken to find how accurately the same subjects can detect accent *via* tactual cues obtained through the single unit receiver. The face of the speaker was fully exposed for the lip-reading portion of the test and completely hidden in the tactual test. E and J were tested together and S separately.

	L	T
E	33 (63.4 p. ct.)	40 (76.9 p. ct.)
J	39 (75 p. ct.)	26 (50 p. ct.)
S	38 (73 p. ct.)	44 (84.6 p. ct.)

APPLICATION OF THE TACTILE METHOD IN PRACTICAL EDUCATION

During the year, we have used the teletactor in relation to the preliminary training and education of a six-year old, congenitally deaf girl. When she came to the laboratory in October 1927, she was—as far as language is concerned—a completely untutored child. She was daily at work in the laboratory from 9 to 12 o'clock, taking out twenty minutes for luncheon. When her working time had aggregated one-seventh of a conventional school year, measured in hours, she had acquired fully one-half the lip-reading and speaking vocabulary that is expected of pupils at the end of their first year in a conventional school. It is quite proper to say that the child discovered her voice in this laboratory. It evidently made a great impression upon her when she discovered that when she did something (babble) with her vocal organs before the transmitter, she *felt* something in her fingers, provided they were in contact with the receiver. She was interested also in the fact that her mother, at the other side of the room (holding a duplicate receiver in her fingers), appeared to be feeling something, too. Playing with the instrument, thereafter, always gave the child a thrill and the mother reported that at home she was playing with her voice "ten times as much as before." Miss Lauritsen was in immediate charge of the work and she used the teletactor daily. She never gave the child a new word or a new sentence, but that the girl was made to feel it in her finger tips. She was also daily required to attempt her own speech in the teletactor and to speak so that the experimenter (Miss L) could feel her voice. These exercises were always great sources of enjoyment. She never wearied of them and we were able to bind up in one sheaf, as it were, tactual and visual impressions of speech and with them the visual impression of printed signs of speech, the motor-sense experience of making printed characters that stand for spoken words and the motor-sense experience of speaking, or attempting to speak.

In another connection, we have discussed the use of the tactile impression *in addition* to the visual impression of spoken words *as an aid in interpretation*. The demonstrations that were made in this relation include one that was accomplished by the cooperation of this young subject.

During the year, the laboratory has had the good fortune to have most enthusiastic and efficient co-workers.

George W. Crane, Ph.D., has been engaged with the Director in this experimental work from its beginning, and more recently in cooperation with Miss Lauritsen in an exceedingly tedious analysis of vocabulary data from 48 of the 56 State schools for the deaf in the United States. Miss Lauritsen was directly responsible for all that has been done in relation to our six-year-old subject, V. G. The success that the laboratory has enjoyed, thus far, is due in large measure to the loyal assistance of these coworkers.

Since September 1, 1927, several articles have been published, or publication has been arranged for (see Bibliography).

Pearson, Karl, and Henry A. Ruger. Teachers College, Columbia University, New York, N. Y. *Studies on the theory of surfaces.*

The following report is submitted as a result of studies undertaken with appropriation of funds by Carnegie Corporation of New York to the Carnegie Institution of Washington for support of Generalized Frequency Surface Research.

INTRODUCTORY STATEMENT

In 1884 Sir Francis Galton collected records on over 7,000 males of ages from six to eighty-two years. These records were in part quantitative and in part qualitative. Sir Francis did not carry through the statistical reduction of this material, perhaps because the relations were not of a simple linear nature and would have required both the development of new statistical techniques and the expenditure of a huge amount of statistical labor. Recently attempts have been initiated and in part completed to reduce and make generally available this and other collections of anthropometric data made by Sir Francis Galton. Such attempts have been made because of both the intrinsic value of the data and of the importance of the historical features of the case.

In particular, the statistical reduction in respect to age of fifteen quantitatively measured traits from Galton's material of 1884 has recently been carried through by Henry A. Ruger with the assistance of Brenda Stoessiger and with the guidance of Professor Karl Pearson. The traits concerned are the following: stature, sitting-height, arm-span, weight, strength of pull, stronger grip, right grip, left grip, swiftness of blow, vital capacity, visual acuity, highest audible pitch, error of judgments of perpendicularity, of bisection and of trisection.

Growth, or age, curves for general tendency and both absolute and relative variability, and correlation coefficients and correlation ratios were obtained between the traits listed and age. These relations with age proved to be non-linear and diverse in character. Consequently, the examination of the net relations between these traits demanded other techniques than those of the customary partial correlation. Study of these net relations, after correction for age differences, was not attempted in the first survey referred to above, but forms part of the scope of the second of the series, *i.e.*, on which the writer is at present working in conjunction with Professor Karl Pearson, and with the counsel of an advisory committee composed of Professors E. L. Thorndike and R. S. Woodworth.

THE PRESENT INVESTIGATION

Included in the purpose of the present examination is, as suggested above, the examination of the net relations, after correction for age, of eight of the fifteen quantitatively measured traits. These traits are in general either of a dominantly anatomical or motor character. They are: stature, sitting-height, span, weight, strength of pull, grip of stronger hand, swiftness of blow, and vital capacity.

The treatment of results is to include not merely the reduction of all scores of a given trait to those of a given, or standard, age and the sub-

sequent correlations of these age-corrected scores, but also a detailed study of the frequency surfaces involved and the bearing of these results on general theories of frequency surfaces.

As a result of work done during the summer vacations of 1927 and of 1928 and of part-time work during the intervening winter, all the scores of these eight traits have been transformed into age corrected scores. Over 56,000 scores were thus transformed and then the entire operation was repeated independently. Something like 500 separate equations were required for these transformations of the original scores. This process has just been completed. In addition to the transformation of the scores about 600 correlation spreads have been set up, each with a population of about 250, there being overlapping of populations. About 400 of these spreads are yet to be checked, and perhaps 300 more are to be set up and checked. In addition to this there are to be 28 correlation tables, each table including the entire population of 7,000 males. Two of these have been set up and the remaining 26 will be constructed as soon as possible. Coincident with this will be the checking of the smaller correlation tables referred to above. The statistical analysis will follow the final checking of the correlation tables or spreads. This will include the finding of the correlation coefficients and correlation ratios for each of the tables concerned, the computation of the means and variabilities of each array of each of the tables and the fitting of curves to these various sets of frequency constants. Following this is to be the comparison of the 28 correlations on the total population of 7,000 with those for the same traits on the various age groups in respect to clarification of the general method employed for age-reduction. Also there is to be the study of the various correlation surfaces from the standpoint of their bearing on generalized frequency surface theories.

FURTHER PLANS AND CONSIDERATIONS

The inclusion of so extensive a program of frequency surface construction and numerical analysis, suggested by Professor Pearson and approved by the Advisory Committee naturally tends toward an extension of time for the total investigation. It is proposed to follow the present study with one bearing more directly on the generalized theory of frequency surfaces.

At least three papers of an empirical or theoretical character are involved in the Frequency Surface Investigation. The first of these, on Growth Curves, appeared in the *Annals of Eugenics* (vol. II, 76-110, 1927). The second paper, on which work is being carried on at present, is based upon the first and involves a further statistical reduction of the same data. The third, more theoretical, paper is to follow.

In addition to this series of three papers it is hoped that the construction or completion of others of a more psychological nature may be made possible, particularly of a study on animal behavior, and of another concerned with the voice.

Acknowledgment of conscientious and efficient statistical assistance in connection with the second paper is due to Misses Butterfield, Cohen, Dorsey, Grady, Kramer, Ransom, Roach and G. J. Ruger all of New York City and to Miss Page and Mr. and Mrs. John Wishart of University College, London.

SEISMOLOGY

REPORT OF THE ADVISORY COMMITTEE

(For previous reports see Year Books Nos. 20-26)

The report of the Advisory Committee in Seismology for the year ending June 30, 1928, may note three outstanding items of progress which have been long upon its calendar:

- (1) The completion of precise leveling to the top of Mount Whitney.
- (2) The readjustment of the primary triangulation net of the western United States which vitally affects all measurements in the California earthquake zone.
- (3) The beginning of actual observations of earth movements at the new Seismological Laboratory and associated sub-stations in southern California.

The re-determination of the height of Mount Whitney is perhaps most significant among vertical dimensions in California. Mount Whitney is immediately adjacent to a zone of active movement to the east which has been carefully studied. If there is still a differential movement going on between the Sierra Block and the adjoining terrane to the east of it the height of Mount Whitney will be its index. It therefore appeared of the first importance in the study of California earth movements in the vertical dimension that the height of Mount Whitney be re-determined. Then too it happens that this elevation has twice before been accurately measured. A new determination will therefore offer one of the very few opportunities now available to discover whether vertical movement has actually occurred along this fault zone during the past thirty years.

Work was begun by the Coast and Geodetic Survey on this re-determination in 1925 and was then carried up to the 8,400-foot bench mark. This year following local arrangements for restoring the trail, the measurements were completed before the end of June. Snow conditions at this season were severe and the work at the upper levels entailed considerable hardships upon the field party. The field observations are now in process of reduction and will be reported later in the year.

The second item of major importance was the completion of the readjustment of all the closing errors in the primary triangulation of the western half of the United States. This readjustment has been in progress at the United States Coast and Geodetic Survey for the past two years and was a task of great magnitude. Its significance to us lies in the fact that the California earth movements which have been the objective of our plans for the past six years are based upon fixed points whose position is determined by this fundamental network. Major Bowie, Chief of the Division of Geodesy, has now in press a paper entitled *Comparison of the Old and the New Triangulation in California*, showing in detail the effect of this readjustment upon the position measurements recently undertaken in the

earthquake zone. With the permission of the Coast and Geodetic Survey significant paragraphs from the manuscript of this paper are here reproduced. For a proper appraisal of the probability of movement along the well-known fault lines of California since the major earthquake of 1906 this paper should be carefully studied. Dr. Bowie says:

"The United States Coast and Geodetic Survey began the reoccupation of triangulation stations in California in 1922, but it is only now that the final results secured can be made available in definite form. This is owing to the fact that the readjustment of the triangulation net of the western half of the United States had to be made before the California triangulation, executed 30 years or more ago, could be accurately compared with the work done during the past six years.

"It can now be definitely stated that there has been no perceptible horizontal movement of the ground at those stations extending from Monticello and Vaca in longitude approximately 122° eastward to Carson Sink in longitude $118^{\circ} 15'$. It can also be stated that there is no definite indication of horizontal shifting of the ground at the stations from San Jacinto and Cuyamaca to Kofa in longitude $114^{\circ} 10'$. This is to say that Mount Lola, Round Top, Pine Hill, Marysville Butte, Vaca and Monticello have not changed in their horizontal positions with respect to Carson Sink; nor have San Jacinto, Cuyamaca, American and Butte changed with relation to Kofa. These are significant facts since they enable us to assume that San Jacinto and Cuyamaca on the south and Round Top and Mount Lola on the north are unchanged points.

"The positions of the fixed points result from the readjustment of the net of the western half of the country in which is included the triangulation of California, executed during the past few years. From the evidence the definite conclusion was drawn that no earth movements occurred at stations between Lospe-Tepusquet and San Jacinto-Cuyamaca. Lospe and Tepusquet are two stations at the western end of the arc of triangulation which extends eastward across California and into Nevada. Since they are at a junction of two arcs of the triangulation net their positions resulting from the general adjustment are very strong."

This conclusion demonstrates that the displacements of 20 feet or more in the vicinity of Santa Barbara, which were announced in the preliminary report of 1924, have not occurred. The stations then supposed to be displaced under severe crustal strain (Arguello-Gaviota) are the adjacent stations immediately south of Lospe-Tepusquet. The present conclusion is strengthened by the fact that arcs of primary triangulation converge upon Lospe-Tepusquet from three directions north, east and south, as Bowie has emphasized. The arc to the east has been run since 1924 and has furnished a new and conclusive check on the whole situation. The present conclusion may therefore be regarded as established, namely, that there are no horizontal displacements in the Arguello-Gaviota region greater than the probable errors of the triangulation, nor is there evidence of especial strain there.

Bowie then reports from the region adjacent to the San Andreas fault to the north and south of San Francisco as follows:

"Of course, everyone is familiar with the fact that much distortion of the earth's surface close to the San Andreas fault occurred during the

earthquake of 1906. This report does not deal with the extent of those local movements but it is an attempt to discover to what extent horizontal movements of the surface occurred at points used as triangulation stations which are at varying distances from the active fault line.

The indications are—"that there has been a definite south or southeast drift of stations Ross Mountain, Mount Hamilton, Loma Prieta, Santa Ana and Hepsedam.¹ Sierra Morena has moved to the northwest and Point Reyes Lighthouse has moved to the north. The most noticeable case of relative earth movement occurs for the pair of stations, Ross Mountain and Point Reyes Lighthouse. There the shifts in position are about 10.4 feet northward for Point Reyes Lighthouse and slightly more than 3.5 feet southward for Ross Mountain. The relative movement of these two stations is about 14 feet.

"The changes at stations Fisher, Cold Spring, Dunn, Clark and Lane, however, are such as to indicate definite earth movements. The change at Cold Spring is 2.7 feet and at Lane 7.4 feet. Although the change at Cold Spring is not very large the station is only 14 miles from Paxton and the ratio of the changes at those two stations to the distance between them is 1/30,000, which is greater than might be expected from the triangulation errors. All of these five stations at which the changes in position are large are close to the San Andreas fault. Station Lane is within a mile of the fault of 1906. The change at each of these five stations is to the south-eastward, which agrees in direction with the changes in position at Ross Mountain and other stations to the southward, which are on the eastern side of the fault."

The situation here developed will afford a most interesting subject for further study, both from the seismologic and geologic view points. No other California region shows definite evidence of very recent movement.

With reference to the advancement of the general program of triangulation and precise leveling undertaken by the Coast and Geodetic Survey in the earthquake zone of California, Major Hodgson kindly prepared the following memorandum:

GEODETIC WORK IN CALIFORNIA

"While no field work has been done in California during the past year on triangulation to test the stability of the triangulation stations, a great deal of work has been done in the office in Washington in the form of computations and adjustments of triangulation and in an analysis of the results.

"It was not possible to make a final test of the changes in geographic positions in California until after the readjustment of the western half of the triangulation net of the United States had been completed. With the completion of this work, a solid foundation was available for the testing of the stability of the points on which the triangulation stations were located. The analysis of this work has now been finished and a report on it, entitled *Comparison of the Old and the New Triangulation in California*, by William Bowie, Chief, Division of Geodesy, U. S. Coast and Geodetic Survey, is now in press. In this report are given the final results of the recent investigation of earth movements in California by means of triangulation. The investigation was started in 1922 and has just been completed. The report now

¹[Since the last previous primary triangulation some time before 1900.]

in press supersedes a preliminary report made by Bowie in 1924, at which time the field work and computations were not sufficiently advanced to permit drawing definite and reliable conclusions. The final results show that the changes in geographic position at a large number of the stations in California are so small as to be comparable with the ordinary unavoidable errors of triangulation. At many of the stations, however, there is rather conclusive evidence of at least relative earth movements at contiguous stations and, at a few of the stations, there is indication of absolute earth movements; that is, movements relative to certain fixed points at a distance from the earthquake zone.

"Lines of first-order leveling were run from San Diego, through Warner Springs and Ramona to Oceanside; from Goleta to Edna; from Santa Margarita to Bakersfield; from Mojave to Barstow, and from El Centro to Colton.

"A line of first-order leveling was completed to the summit of Mount Whitney. This line was begun in 1925 and carried up the mountain slope to the 8,400-foot level, where field work had to be abandoned because the trail had become blocked by snow and falling stones. This year, by going around the blocked portions of the trail, the party reached the summit with the leveling late in June 1928."

LOCAL DISPLACEMENTS ALONG KNOWN FAULTS

The network of primary triangulation which is thus being extended over those regions of California where earth movements are known to occur is perforce a scale of large units. The stations are from 10 to 50 miles or more apart and very few of them happen to fall on, or sufficiently close to, known faults to reveal local displacements at the fault trace or the character of the strains produced in the ground back of them.

Accordingly something over a year ago a plan was prepared within the Committee for lines of monuments perpendicular to certain of the more important faults and extending for 4 or 5 miles on either side of these. Three such lines were contemplated at appropriate places in southern California in order to determine the kind and amount of movement now going on in its main fault zones. Later the plan was altered to bring these into one continuous series extending from Bear Lake to Newport Beach nearly perpendicular to all the great faults of the region. Also under advice of the Coast and Geodetic Survey the line of monuments was altered to a line of triangles so arranged that monuments close to the faults should be spaced close together, and in the intervals much farther apart. Thus a suitable number of monuments would be aligned perpendicular to the great faults in such a manner that the character and amount of displacement immediately at the fault and at various distances away from it could be determined, whether the movement were in the nature of a slow creep over a period of years or a sudden release of strain, such as occurred on the San Andreas fault in 1906. It is hoped that with the cooperation of the Coast and Geodetic Survey this plan may be carried out during the coming year.

LABORATORY WORK¹

At the close of the previous year, much of the required instrumental equipment had been installed at the Seismological Laboratory and at the outlying auxiliary stations at Riverside, Santa Barbara and La Jolla; but, except in part at Riverside, sufficient time had not elapsed for this equipment to attain a stable operating condition. Also, at all the stations, the time-keeping clocks initially provided were intentionally of temporary character, to serve inexpensively while awaiting progress with the radio time-marking plan. Unfortunately, these temporary clocks have proved unexpectedly inadequate for routine time keeping, in fact, hardly serving any other purpose than to divide the seismographic lines into intervals one minute in length, approximately. No vertical component seismometer was installed anywhere except a single short-period vertical seismometer of the torsion type set up for trial at the Seismological Laboratory.

EXPERIMENTAL WORK

The need, emphasized from the first, of adequate time keeping at all the stations, preferably by means of radio time signals, sent once each minute from a central station, led to intensive work on this problem shortly after the beginning of the year under report. Preliminary consideration of the use of long waves, 1,000 meters more or less, demonstrated that a transmitting station having sufficient power to send out signals which could be received reliably would cost much more than any amount which is considered available. Such a station would also be costly to maintain and operate. Consequently, attention was turned to the utilization of short waves for this purpose. At first this appeared promising, but as experimentation proceeded many difficulties were encountered. This led to the conclusion that, at the present stage of development, these waves can not readily be utilized for our purpose. This is due to the fact that within the range of distance over which we desire to operate, say 10 miles to 300 miles, the reception of these waves is unreliable and at times impossible, especially when the signals must be recorded automatically. This is on the assumption of a transmitting station placed at no great distance from Pasadena. We have considered the alternative possibility of a transmitting station located at a point fairly distant from Pasadena, say 1,000 miles, more or less, in order to place our stations outside the "skip zones." However, information published recently by the Bell Telephone Laboratories, and by others also, indicates that at these distances, too, the short waves can not be received reliably, whereas, *reliability* is the essence of our requirement. With these waves, the signal strength is found to vary considerably, both diurnally and with respect to the seasons of the year. It is concluded that, at present, reliable operation utilizing these waves would require equipment beyond our means, wherever the sending apparatus might be placed.

Recent experiments promise a temporarily adequate solution and method. It has been found possible to receive, and record automatically on photographic paper, signals sent out by large commercial transmitting stations

¹ Extracted from the Report of H. O. Wood, Research Associate in Seismology.

which broadcast messages almost continuously throughout all or a great part of every day. There is little interruption of service, and experimental reception and recording has proved reasonably reliable. This indicates the following method for our temporary use. On an auxiliary recording drum at each of our stations the entire daily output of signals from a suitably chosen large transmitting station could be recorded automatically by means of relatively inexpensive receiving apparatus and optical recording systems. On the auxiliary drum there would also be recorded each minute time-mark made by the station time-marking clock, at the same instants as the marks made on the seismogram. We would thus have at each station *identical* records of the dot-and-dash commercial radio signals, with which the local clock signals could be compared, minute-by-minute, throughout the day—and so, at the expense of considerable inconvenience and some additional risk of error in the labor of making the necessary comparisons, we would have a system in which the time of any sharply marked phase of the seismogram could be determined with the same order of accuracy, for *relative* (station to station) time, as by means of minute-to-minute time signals transmitted from a central station of our own. This system would offer the advantage of utilizing a station of greater power than any we could readily afford to maintain. Its disadvantages, apart from the relatively small matter of operating at each station an auxiliary recording drum with its attendant optical and driving apparatus, consists in the burdensome inconvenience and increased chance of error involved in carrying through the necessary comparisons. With this system, for some purposes a very ordinary time-keeper would serve well enough as a time-marking station clock, but to avoid serious and burdensome inconvenience the station time-marking clocks would best be excellent time-keeping mechanisms.

Experiments have been undertaken with the aim of providing at reasonable cost excellent time-keeping clock mechanisms at each station. In a region where local strong shocks occur no pendulum clock, even though of superior accuracy, can be relied upon for routine time-marking since it would be likely to fail when most needed. Therefore, for time control we have turned to the use of a 60-cycle tuning fork maintained in oscillation, at sufficiently constant temperature, by an electron-tube assembly analogous to that which maintains the reed-oscillator in our present motor driving apparatus. The system more recently devised is superior to that previously developed in that dependence upon the action of relays is avoided, which greatly increases reliability of operation in the hands of unskilled attendants. It has been demonstrated recently in the Bell Telephone Laboratories that a method like this provides as good time-keeping as an excellent marine chronometer. Alternating current of 60-cycles, controlled in frequency and therefore in time-keeping quality by this tuning fork assembly, serves to operate one or more Warren Telechron clocks, which thus provides time-marks as accurate as the tuning fork. This method is still in an experimental stage but no difficulties are anticipated in bringing its development to a successful conclusion.

Incidentally, assuming successful developments, this same tuning fork assembly, controlling additional Warren motors, will simplify and improve

the system for driving drums previously developed. Under this method the drums will rotate as accurately as the superior time-marking clock provided as described above. It is considered that this method should be used in new installations, and that the older less accurate method should be replaced as early as is practicable, since the new system also will provide the accurate station time required.

Experiments have been begun with an accelerometric seismometer on the principle of the carbon pile as used by McCollum and Peters in the "Electric Telemeter" devised by them for engineering tests. They developed successfully a simple and reliable mechanism which we expect to modify and adapt for seismometric uses. Our experiments along this line are still in an early stage.

As one outcome of this experimental work there will soon be published a paper with the title *Note on the Theory of Regenerative Oscillatory Systems*.¹ This paper derives a quantitative relation between the operating frequency, the damping, and the phase displacement of the driving force in regenerative systems, such as clocks, electrically driven tuning forks, piezo-electric oscillations, etc.

Early in the year under report, a compressed flat-spring, vertical-component seismometer was constructed under the direction of Dr. Sinclair Smith of the Mount Wilson Observatory staff in accordance with an idea original with him. This device has much promise, but in the original construction it was not possible to raise the period of use much above five seconds. More recently a second model has been constructed which readily permits adjustment to a period of twelve seconds or more. This is now being tested.

A determined effort to develop an adequate low-priced "intensity meter" has occupied attention at intervals throughout the year. To solve the problem in ways considered adequate presents unexpected difficulties. Less adequate solutions would be comparatively easy to work out.

STATION ACTIVITY

An important aim of this work is the location of sources of local earthquakes by means of the seismometric data of two or more stations, together with the solution of problems involved in or associated with this. This group of problems differs in two important aspects from those commonly encountered in seismology and those, in consequence, most frequently discussed theoretically, (a) the stations used are the same in all, or nearly all, instances, and (b) the region to be studied is small, so that the curvature of the earth can be neglected, at least in all but special cases. Such problems have, of course, received a certain amount of consideration in work already published. However, under the circumstances outlined, considerable simplification in method is permitted in attempting the solutions of these problems.

For the location of an earthquake origin under these conditions there are in general four unknown quantities—the two coordinates of the epicenter, the depth of the hypocenter, and a constant, K , which is the ratio of the

¹ By Hugo Benioff.

distance of the hypocenter from any station to the time interval, S-P, at that station. This assumes rectilinear propagation of the seismic wave-motion.

These four quantities can be determined directly if S-P is observed at four stations. If K is known already (this constant has often been approximated, but unfortunately the values found differ considerably), the location of the source can be found from the data of three stations. Therefore, unless the source is clearly very close to one of the stations, it may be assumed that its depth is small in comparison with its distance; the *epicenter* can then be located from the data of three stations.

Our records show phases agreeing in a general way with those found by Jeffreys; but the absence of transmission-time data renders comparison with his results uncertain. Also, the suggestion is strong that still other significant phases appear frequently in the "preliminary tremor" part of the seismogram.

Analytical and geometric methods for determining the position of the origin have been developed by Dr. Charles F. Richter, who has served as part-time assistant in seismology during the greater part of the year. These were applied to several actual shocks. Especial pains were taken to locate the source of a shock which was on the verge of being distinctive at Bishop, California, on September 17, 1927. It was found that relatively small uncertainties in the positions of the *stations* were sufficient by themselves to cause relatively large uncertainties in the computed position of the hypocenter. In this case only an approximate solution could be evaluated. Further, the values of S-P measured on the seismograms from the different stations were inconsistent to some extent, and this is due to difficulty in identifying *precisely* the phases where the preliminary motion is complicated. It is concluded that systematic analytic or geometric methods for origin determination can not be employed in a routine way until transmission data for near distances become available, and the identification of phases is put on a more certain basis. This requires an accumulation of data, with adequate time-keeping at all stations.

Simpler methods, therefore, have been employed in working over the considerable amount of data now in hand, including information from four epicenters well determined in other ways. Advantage also has been taken of the fact that the stations at Pasadena, Riverside, and Santa Barbara lie almost precisely on an arc of a great circle, or, neglecting earth curvature, on a straight line. This makes the determination of the *distance* from the source to the station independent of its depth, and in this respect greatly simplifies the work. With shocks in which S-P is clear and definite at all three of the stations, by graphical construction on a map it is fairly simple to evaluate K and the distance of the hypocenter from the three stations. From all the data of sufficiently good quality the constant K has been determined approximately and tentatively. In the present status of the determination, the limits of error are fairly large. The value thus found is, K equals about 5' of arc, or nearly 9.25 km., for each second of the S-P interval. This value is larger than that usually given, but it coincides with

the values stated to the writer some years ago by Professor Harry Fielding Reid, of the Advisory Committee. We are now making use, pending more precise data, of this value of K in computing shock origin-distances from out stations.

Leaving out of count in this place the preliminary registration at the experimental station at the Mount Wilson Observatory office and at the Norman Bridge Physical Laboratory at the California Institute of Technology, reported upon in previous years, the dates of the first records of the new network stations follow: at Riverside, October 19, 1926; at Pasadena (Seismological Laboratory), March 19, 1927; at Santa Barbara, May 10, 1927; at La Jolla, May 24, 1927; and at Mount Wilson, April 23, 1928.

From records written at these stations, supplemented by other information, epicenters have been determined for about seventy local shocks—about thirty distinguishable epicenters with several shocks from the same general source in a number of instances. In quite a number of cases the sources are limited to a small polygon of error, in other cases the sources are located moderately closely, while in a few cases the polygons of error are relatively large. A few additional shocks have been located somewhat doubtfully.

In the list above referred to are three minor strong shocks, of mildly destructive intensity within small epicentral areas: one in Monterey Bay, on October 22, 1926; one at Calexico, January 1, 1927; and one off the coast of Santa Barbara County, on November 4, 1927.

The epicenters of a number of shocks, some of which have been felt along the coast, especially at Ventura, are found to lie at several points to the south of Santa Cruz Island, apparently along the steep eastern declivity of a considerable depression shown by the submarine contours determined by acoustic sounding.

Another group of epicenters, associated with shocks felt rather sharply in the region of Santa Monica Bay, appears to be to the northeast of Catalina Island and south of point Dume.

Since the establishment of our network of stations, the San Andreas fault-zone has been relatively inactive. A shock felt at Bakersfield and in the southern San Joaquin Valley on July 7, 1927, probably originated nearby on this fault. Also, a considerable number of small shocks, mostly occurring during 1928, have been recorded at Riverside and Pasadena, but not at the stations at La Jolla or Santa Barbara. These appear to come from the *eastward extension* of the San Andreas zone in the desert region.

The slightly destructive shock at Calexico, with its numerous after-shocks, originated on the southeastward extension of the San Jacinto fault zone. Small shocks still occur in the same general vicinity. There is also some evidence, more doubtful in character, of activity on this same line south of the Mexican border. In April and May 1928, several shocks were recorded which appear to have originated on the San Jacinto fault near San Felipe Creek, west of the Salton Sea.

Several-shocks felt at Anaheim, Santa Ana and vicinity, have almost certainly originated in the Whittier fault.

A number of small shocks, especially in December 1927 and January 1928, are located in the vicinity of Inglewood, but not precisely enough to discriminate among the several faults under suspicion in that vicinity.

Shocks on December 31, 1927, and subsequently, appear to have originated near the shore east of Point Dume.

Shocks felt in San Diego County on August 14, 1927, and November 6, 1927, originated not far from the Barrett Dam reservoir.

A shock, with two distinctly perceptible maxima, which closely resembled an explosion or blast and was mistaken by many for such an artificial disturbance, was felt in Pasadena, Los Angeles, and surrounding region on October 8, 1927. Its epicenter is found to lie just off the coast of Orange County.

A shock on April 29, 1928, recorded at all our stations except La Jolla, appears to have originated on the Garlock fault.

The records of the shock at Calxico at 2^h 34^m a.m. on January 1, 1927, very closely resemble those of the shock on February 12, 1927, from the same source. The records written by the telet seismic torsion seismometer then in operation at the experimental station at the Mount Wilson Observatory office are almost superposable in the two instances. On the records made by the short-period instruments at Riverside the resemblance is less perfect, but it is still very striking. Moreover, at the latter station both horizontal components were recorded; the N-S records written there differ remarkably in general aspect from the E-W records, but the resemblance for each component on the two dates is just as marked. A considerable number of resemblances similar to that above discussed have now been observed in the case of smaller shocks. A strong suggestion arises, of course, that in such cases the record is due to a single impulse, or some very simple causing disturbances, the complicated record motion being a function only of the path and the characteristics of the recording seismometer.

Such resemblances are not characteristic of most shocks, of course. Not only do obviously multiple shocks occur, but the complicated aspect, at least at the nearer stations, of the Santa Barbara shock and that off the coast on November 4, 1927, suggest an initially complicated motion. In considering this, however, it must be noted that the Calxico shocks, which as suggested above suggests a simple mode of causation, are reported to have been perceptible for an appreciable interval in their epicentral area.

These facts suggest strongly that two types of shock actually occur here. In one case, which is not necessarily the case of greater energy exclusively, the causative disturbance is complex, or the region of origin is extended, or both these things are true; in the other case, the region of origin is small and the causative disturbance is simple, *e.g.* a single larger impulse, perhaps accompanied by smaller vibrations which are extinguished by damping at moderate distances.

In addition to his very considerable part in the work reported upon immediately above, to which contributions were also made by M. D. Shappell, who also served as part-time assistant in seismology during the greater part of the year, Dr. Richter is giving some consideration to the question

of periodicity in the occurrence of the larger Californian shocks, with especial reference to variation of latitude. It is too early to draw any conclusions as yet, despite the appearance of several striking coincidences. This is also true of an attempt to correlate the larger Californian shocks with seismic activity in other parts of the globe.

The torsion-type vertical-component seismometer tested at the Seismological Laboratory has behaved as it theoretically should. Its proper period can not well be raised above 0.3 second without encountering stability and temperature difficulties. With such a period it has proved stable and not much disturbed by the temperature variation to which it is subjected. But its sensitiveness is made smaller than in the horizontal component apparatus with proper periods of 0.8 to 1.0 seconds. Except for the stronger shocks its records are less useful, and where the shocks are perceptible it tends to be too much disturbed by violin-string vibration, despite its oil-damping against this. It did, however, register plainly, though with very small amplitude, a major blast set off at Colton, near Riverside, on April 1, 1928. (No advance information in regard to this blast was given out, so intensive study of it was impossible.)

At intervals during the year work on the Santa Barbara earthquake has been carried on in cooperation with Professor Perry Byerly. The completion and preparation of this work for publication must now await his return to California next spring.

Both Professor Byerly and ourselves have found that we can not yet dispense with auxiliary information, such as reports by observers, in the intensive study of particular shocks. We have therefore worked out a plan for securing such information in cooperation and with the aid of the U. S. Coast and Geodetic Survey. It is expected that this can be put into operation in the not far distant future.

OTHER INSTRUMENT DEVELOPMENT

Dr. Frank Wenner of the Bureau of Standards, who has been associated from the beginning with the work of this Committee, has recently developed a new type of horizontal teleseismograph which has given most satisfactory records in preliminary trials.

It is nearer to the Galitzin than to the Wood-Anderson torsion type of instrument, but is small and apparently equally competent as a long-period or short-period instrument. The torsion seismometer has given some difficulty in reaching, maintaining and restoring after disturbance, the particular long-period adjustment desired. The new instrument offers greater facility in these respects.

The Wenner seismograph is to be placed in routine service (long-time test) at the station of the U. S. Coast and Geodetic Survey at Cheltenham, Maryland. A very complete report both of its theory and of its performance is in preparation and will soon be available.

Dr. Wenner is now engaged in designing a vertical-component instrument upon similar principles. This appears at the moment to be the greatest desideratum in the projected studies of California earth movements with which this Committee has been engaged.

RECOMMENDATIONS

It is recommended that provision be continued:

- (1) For further experimental work on vertical-component instruments for the stations already designated:
- (2) For the further study of minute-to-minute time signals for simultaneous record at all of the stations.
- (3) For further experimental work in the study of cumulative stresses (tilt mechanism).
- (4) For two additional branch stations at appropriate points to be selected.

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Advisory Committee in Seismology

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